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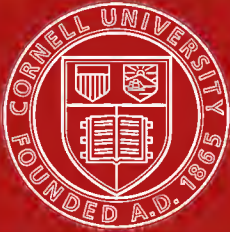
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ENGLAND AND WALES.

THE GEOLOGY OF

THE COUNTRY AROUND

M A L L E R S T A N G,

WITH PARTS OF

WENSLEYDALE, SWALEDALE, AND ARKENDALE.

(EXPLANATION OF QUARTER-SHEET 97 N.W.
NEW SERIES, SHEET 40.)

BY

J. R. DAKYNS, M.A., R. H. TIDDEMAN, M.A., F.G.S.,
R. RUSSELL, C.E., F.G.S., C. T. CLOUGH, M.A., F.G.S., AND
A. STRAHAN, M.A., F.G.S.

(PARTS BY J. G. GOODCHILD, F.G.S., C. E. DE RANCE,
ASSOC. INST. C.E., F.G.S., G. BARROW, F.G.S., AND
F. H. HATCH, Ph.D., F.G.S.)

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FRONTISPIECE.



View of Wild Boar Fell from Cote Wold, near Hawes Junction. The Cross Fell range seen in the distance through the Mallerstang Valley.
From a sketch by C. T. Clough.

P R E F A C E.

THE geological examination of the area described in this Memoir was begun by Mr. (now Professor) T. McK. Hughes, and many of the lines in the south-western part of the map, more especially among the Silurian Rocks, remain as originally laid down by him. On his retirement from the staff of the Geological Survey, the mapping was carried on by Mr. Goodchild under the superintendence of Mr. Aveline, but was ultimately completed by Messrs. Dakyns, Tiddeman, Russell, De Rance, Clough, Strahan, and Barrow, under the superintendence of Mr. Howell. In the final revision of the complicated series of contemporaneous and intrusive igneous rocks, Mr. Strahan had the valuable assistance of Messrs. Marr and Harker, whose published work is well known to geologists. Dr. Hatch also examined the rocks in the field, and furnished petrographic notes upon them.

The present Memoir has been written by those who finally completed the surveying of the ground, but the notes made by Professor Hughes and Mr. Goodchild have been freely used, while in the case of the Stockdale Shales advantage has been taken of a valuable paper by Mr. Marr and Dr. Nicholson. The whole Memoir has been edited and arranged by Mr. Strahan.

Of the area described in the following chapters, a large proportion lies at an elevation of more than 2,000 feet above the sea. Embracing a portion of the main water-parting of England, it includes the sources of the Rivers Ure and Swale, which drain into the North Sea, and the Lune and Eden, which flow to Lancaster and Carlisle respectively.

The oldest rocks in the district are the Coniston Limestone series and accompanying igneous masses, followed by the Upper Silurian groups. These are covered unconformably by the Carboniferous system, which spreads over the main portion of the area and shows a great development of the lower groups up to the Millstone Grit. The late Professor Phillips selected the top of the Main Limestone as the base of the Millstone Grit. But in mapping the whole of the North of England the Survey has been compelled to abandon that line and to include in the Carboniferous Limestone series all the strata up to the base of the Ingleborough Grit.

One of the distinguishing characters of the ground here described is the remarkable scenery produced by the denudation of gently inclined strata. The great cake of Carboniferous formations has been deeply trenched by the various streams, and the once continuous sheet of Millstone Grit has been reduced to detached outliers capping the higher ridges and hills.

A bibliography of the more important works relating to the geology of the district will be found in the Memoir on the Geology of the Country around Ingleborough, &c. (Quarter-sheet 97 S. W.)

3rd June 1891.

| ARCH. GEIKIE,
Director-General.

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THE GEOLOGY OF

THE COUNTRY AROUND

MALLERSTANG,

ETC.

CHAPTER I.—INTRODUCTION.

THE area embraced by this map, with the exception of the larger valleys and of a small area near Kirkby Stephen, consists entirely of moorland. It reaches its greatest height of 2,340 feet in the Great Shunner Fell. Other points of maximum elevation are High Seat 2,328, Wild Boar Fell* 2,323, Hugh Seat 2,257, Swarth Fell 2,235, Lunaset 2,218, Baugh Fell† 2,216, Rogan's Seat 2,204, Sails 2,185, Water Crag 2,176: so that the district is of great elevation. It is also bordered on the west, south, east, and north-east by areas of high elevation, and it contains the head-waters or sources of the Lune, Eden, Swale, and Ure (or Yore).

WATERSHEDS.

The country is physically divided into two unequal portions by a great trench traversing the hills as a continuous valley in which flow the rivers Ure and Eden; for one can walk from the Humber to the Solway, crossing the water-parting of England imperceptibly, by following up the Ure and going down the Eden, thus passing right through the heart of the Pennine Range, without once leaving a narrow valley hemmed in by steep fells.

The Eden and Ure take their sources from two gills which run down the east flank of this long continuous valley and, on

* The spelling of this and all other names is that given on the Ordnance Map. In this case, however, it is probably wrong. The native pronunciation is Wilber or Wyber, the l sound being exceedingly faint. There is no sound of d in the word.—J. R. D.

† By the old authors frequently spelt Bar or Bow Fell.

arriving at the bottom, flow off to the north and south respectively. The fell in which they rise is Lunds Fell, and the waters go by the name of Hell Gill and Ure Head.

The Eden flows north over Carboniferous rocks of the Yoredale Series and the Great Scar Limestone, until it arrives at Whaiton Hall, where it enters upon the overlying red Permian Rocks. West of the Eden Valley and its southern continuation in the drainage of other river-basins, is a line of fells running about north-north-east, consisting, as we proceed from south to north, of Baugh Fell 2,216 feet, Swarth Fell 2,235 feet, Wild Boar Fell 2,323 feet, Little Fell 1,831 feet, Greenlaw Rigg 1,318 feet, and Birkett Common 1,150 feet. This line of hills is here crossed by the Eden and continues on the other side in a range of buttresses subsidiary to the higher fells which bound the valley on the east and culminate in Mallerstang and Nine Standards. These lesser hills are Great Bell 1,230 feet, and Hartley Birkett 1,255 feet.

Wild Boar Fell is drained on the north-west by Scandal Beck, which runs into the Eden, and on the west and south-west by the sources of the Rawthey, a part of the Lune drainage. The longest affluent of the Rawthey lies between Wild Boar Fell and Baugh Fell, in Uldale, running to the north-west. Another source, Sally Beck, which runs S. 30° W., lies in a valley coinciding with the upper part of Scandal Beck, and situated on a branch of the great system of faults hereafter described.

West of this valley lies a great mass of fells of Silurian Rocks extending to Tebay on the west and Sedbergh on the south, chiefly within the Lune drainage-system; not more than three square miles of it belonging to the Eden basin, with which it is connected by Scandal Beck. This beck drains, besides, a high area of Carboniferous Limestone comprised in Ash Fell and part of Crosby Garrett Fell, through which it passes by the narrow defile of Smardale, soon entering a drift-covered area and coursing over Permian Rocks from near Smardale Station onwards to its junction with the Eden. The other part of Crosby Garrett Fell also drains into the Eden by Potts Beck, called lower down Waterhouses Beck, in the north-west corner of the map.

The Ure flows south to the Moor Cock near Hawes Junction, where it turns eastward down Wensleydale close along the southern edge of the map. It is joined by several large affluents on both sides, the principal of which, as far as this map is concerned, is the stream from Cotterdale.

The water-parting between the Ure valley and Garsdale Head is so ill-defined, that whilst crossing it you scarcely perceive you are passing from one dale into another; and the stream that forms the boundary of the north and west Ridings of Yorkshire, about one third of a mile east of Dandry Mire, runs sometimes into the one dale and sometimes into the other. At present it runs into the Ure, but an old channel and alluvial

flat leads from it into Garsdale. After crossing the water-parting however, we descend somewhat rapidly into Garsdale.

With the exception of a narrow strip which drains into the Eden, the whole of the north-eastern portion of the ground included in the map drains into the Swale, either directly or by way of Arkendale.

AGRICULTURE, &c.

Nearly the whole of the area comprised within the limits of this map consists of pastoral land of one kind or another. Whatever may have been the case under older systems of cultivation pursued in this district the whole of the arable land is at the present day confined to a small area in the neighbourhood of Kirkby Stephen, and extending over an area bordering upon the Eden not much more than one and a half square miles. Even here the high annual per-centage of wet and cold days renders this form of agriculture irregular and uncertain in its results.

Meadow-land, *i.e.*, grazing land that is periodically mown for hay, is for the same reason generally confined to the lower ground of the valleys; for even where favourable local circumstances have been improved upon by a higher system of cultivation than usual, haymaking is often a complete failure. Most of the meadow-land is situated upon the loamy alluvial deposits near the streams; but the lower slopes of the hills are frequently overspread with a covering of loamy soil transferred, in the form of rainwash, from the surface of the rock nearer the summits.

From the meadow-land zones of rough grazing land, or pasture, follow the slopes of the hills, and extend upward to the moorlands of the summits. In consequence of the varied nature of the surface appropriated for this purpose no general description can be given, as there is every gradation from the dry soils with their short, sweet grass, through the coarser grass and rushes developed upon the stony clays, to the rough heathery pasture fostered by the patches of peaty soil that occupy the spaces between the masses of weathered rock. Here and there, and especially on the outcrop of the limestones, large patches of perfectly bare rock occur; but even in these patches lines of soil settled in the joints frequently nourish a fairly abundant vegetation.

Above the pasture nearly the whole of the surface not occupied by crags, weathered blocks, or bare rock of any kind, consists of moorland, based upon a covering of peat, which ranges in thickness from a few inches up to as much as 10 or 12 feet. Here and there, near the head-waters of the streams innumerable gullies branch out in all directions and cut the peat up into detached islets with wet, coffee-coloured slopes, and summits clothed with tufts of heather and the other vegetation of the moorlands. Vegetation of a similar character prevails all over the area covered by the peat, and only occasionally gives place to herbage consisting of the coarser grass and rushes.

The moorlands afford feeding ground for the hardier breeds of sheep during the open weather, while the oxen and the other breeds of sheep are grazing in the pasture-lands below; the meadow land is used for grazing purposes, chiefly for cows, from the autumn until the spring. The Wensleydale cheeses are well known, rivalling those of Stilton in quality, to which they are like in character. They are made from milk supplied not alone by Wensleydale, but also by the neighbouring parts of Swaledale. Butter-factors collect the Swaledale butter and take it over once a week to Hawes market.

Swaledale is also the seat of a considerable mining industry; and was formerly so to a much greater degree than it is now; for of late years the mines have greatly fallen off, and many of them have been quite abandoned. This is doubtless due to two co-operating causes, viz., the low price of lead, chiefly owing to the development of Spanish lead-mines, and the exhaustion of the more productive and more accessible veins.

The population of Upper Swaledale is considerably greater than it would have been had no mines existed to help the farming interest. We should not then have seen the fields climbing up the steep dale-sides so determinedly, nor so many comfortable homesteads nestling under well-grown trees. At present (1883) many of the miners are compelled to emigrate or leave for work in other parts of England, and it is said that owing to this cause the population of the district has decreased by at least one-third within the last 10 years. To many persons the abrupt sides, narrow gorge-like character, and isolation of Swaledale, render it the most attractive of all the Yorkshire dales.

TABLE OF STRATA.

The following is a general list of the strata occurring in the district now under consideration:—

RECENT AND POST-GLACIAL.	{ Alluvium. Peat. River Terraces.
GLACIAL.	{ Gravel. Boulder Clay.
TRIAS.	Soft red sandstone (St. Bees Sandstone).
PERMIAN.	Red sandstone and brockram.
	A. Grit of Shunner Fell top. Shale, with some thin fossiliferous limestone.
	B. Grits of Pickersett Edge, Wild Boar, and Swarth Fells, Rogan's Seat, &c. Shale and sandstone.
	C. Calcareous sandstone and flags. Shale and sandstone.
MILSTONE GRIT.	D. Grits, of White Walls and Low White Scar on Wild Boar Fell, Low Loven Scar, &c. Shale and sandstone, with the Tanhill Coal at or near the base.
	E. Grits of Howgate Edge (Butter tubs) = the Ingleborough Grit.

CARBONIFEROUS LIMESTONE SERIES.	YOREDALE ROCKS.	Shale, probably absent in places.
		Gannister-like sandstone, often double, with a coal between the two beds (= the Grindstone?)
		Shale, with two thin, fossiliferous, calcareous beds (THE FELL TOP LIMESTONES).
		THE CROW CHERT AND LIMESTONE.
		Sandstone and shale (the Ten-Fathom Grit).
		Shale.
		Limestone or chert (THE LITTLE LIMESTONE).*
		Sandstone and shale (the Coal-Sills), with a thin coal.
		The main chert.
		THE MAIN LIMESTONE.
		Sandstone, with a thin coal near the top.
		Shale.
		Chert.
		THE UNDERSSET LIMESTONE.
	Sandstone, with a thin coal.	
	Shale.	
	Limestone, thin (THE THREE-YARDS LIMESTONE).	
	Sandstone and shale.	
	Limestone (THE FIVE-YARDS or PHILLIPS' IMPURE PRODUCTAL LIMESTONE).	
	Sandstone and shale.	
	THE MIDDLE LIMESTONE in three divisions, viz., the Middle Limestone (proper) above, the Cockle-shell in the middle, and the Single Post below.	
	Sandstone, flags, with a thin coal in the upper part.	
	Shale.	
	THE SIMONSTONE LIMESTONE.	
	Sandstone and shale with thin Limestones.	
	THE HARDRAW SCAR LIMESTONE, occasionally in two beds.	
	Sandstone and shale.	
GREAT SCAR LIMESTONE SERIES.	THE MELMERBY SCAR SERIES, consisting of alternations of limestone, shale, and sandstone above, and of thick and pure limestone below.	
	THE ASH FELL BEDS; alternations of sandstone, limestone, and shale.	
	THE RAVENSTONEDALE LIMESTONE SERIES.	
LOWER LIMESTONE SHALES.		
BASEMENT BEDS; red conglomerate and sandstone.		

Unconformity.

UPPER SILURIAN.	{	Bannisdale Slates.
		Coniston Grits.
		Coniston Flags.
LOWER SILURIAN.	{	Stockdale Shales. { Pale Slates (Browgill Beds).
		{ Graptolitic Mudstones (Skelgill Beds).
	{	Coniston { Ashgill Shales.
		Limestone { Contemporaneous felsite (rhyolite) and ash.
		Series. { Limestone and shale.

Intrusive Igneous Rocks.

Diabase.

Mica-trap and andesite dykes.

Felsite (microgranite), as sills and dykes.

* This, with the sandstone and shale below it, constitutes the cherty and calcareous series known as the Red and Black Beds.

INTRODUCTORY ACCOUNT OF THE ROCKS.

The Silurian Rocks form the group of hills, known collectively as the Howgill Fells. The group extends from Tebay to Sedbergh, but its height declines generally towards the north, and along Ravenstonedale its surface dips gently beneath the Carboniferous Rocks. Owing to the contorted and faulted character of the strata it is difficult to depict in general terms the structure of the country. On the whole, however, the rocks may be described as forming a series of domes, which have their centres of elevation close to the fault bounding them on the east, and which pass westwards into a series of minor flexures, subordinate to the anticlinal axis which ranges through Grayrigg Forest.*

The oldest rocks here displayed form part of the Coniston Limestone Series. They consist in the lowest part exposed of dark shales with bands and lenticular masses of black limestone. Upon these, in the northern part of the district, rest thick well-bedded felspathic mudstones, probably fine volcanic ashes, which here and there contain a band of coarse volcanic breccia. The ashes are followed by lava-flows of close-grained felsite (rhyolite), usually pink, and these by laminated sheets of fine ash which graduates upwards into the more shaly upper division of the Coniston Limestone Series, known as the Ashgill Shales. In the southern part of the district these volcanic rocks are unrepresented, and the Ashgill Shales lose much of their thickness, as though they were overlapped in this direction by the Upper Silurian Rocks.†

The lowest member of the Upper Silurian Series consists of black pyritous strata, known as the Graptolitic Mudstones or the Skelgill Beds, so named by Mr. Marr from the beck of that name near Ambleside. Upwards these are interstratified with pale bands and eventually pass into the pale-green and felspathic-looking shales known as the Pale Slates (the Browgill Beds of Mr. Marr); with which they constitute the Stockdale Shales, as coloured on the map.

The Coniston Flags succeed the Stockdale Shales in a similarly gradual manner. They consist of blocky and flaggy mudstones with occasional sandy bands and with calcareous concretions. Towards their base *Monograptus priodon* occurs in profusion. Upwards they graduate into the tough fine-grained grey grits, which constitute the mass of the Coniston Grits. The Bannisdale Slates consist of alternations of dark-grey and olive mudstones with flags, thinly-bedded grits, and partings of roughly cleaved shale. A portion only of this sub-division is exposed to view in

* Geology of the Country around Kendal, Sedbergh, Bowness, and Tebay (Geol. Survey Memoir), 2nd ed., pp. 1-3, 1885.

† The contemporaneous felsites in the Coniston Limestone Series of this neighbourhood were first recognised as such, and distinguished from the intrusive felsites, by Mr. J. G. Goodchild.

this district, the upper beds being concealed beneath the Carboniferous Rocks of Ravenstonedale.

All these members of the Silurian system are more or less penetrated by intrusive igneous rocks, the bulk of which, however, occur in the immediate neighbourhood of the domes of elevation already alluded to. The intrusive rocks fall naturally into three groups, namely, (1) diabase, which occurs as bosses and dykes intruded through the Pale Slates; (2) mica-trap, which occurs as dykes in all the Silurian Rocks; (3) felsite (microgranite), which occurs as "sills" intruded between the bedding-planes of the Coniston Limestone, Pale Slates, and Coniston Flags, or as dykes in any of the Silurian Rocks. A dyke of porphyrite or altered andesite has also been observed in Coniston Limestone. On these rocks Dr. Hatch makes the following observations:—

"(1.) The diabase is a compact dark-coloured rock, and much decomposed, the lath-shaped feldspars being kaolinized, and the augite mainly converted into an aggregate of hornblende-fibres (uralite). Iron-ore occurs in scattered granules.

"(2.) The mica-traps or minettes are compact rocks, usually varying in colour from black to light-grey, but occasionally they are of a reddish-brown or cream tint. Their most characteristic feature is abundant brown mica disposed through the rock in lustrous plates. In some cases these are of some size; in most of the rocks, however, they are minute specks, present in countless numbers, giving the rock a glistening appearance. Under the microscope the mica sometimes appears in regular six-sided plates, but more frequently in ragged patches and blades. It is a dark-brown biotite, probably meroxene. Penetrating the mica, fine needles of apatite are often to be observed. Another important feature in these rocks is the presence of carbonate of lime in considerable quantity. In many cases they are so highly charged with calcite as to effervesce freely with acid. This mineral has, in many cases, completely replaced the original constituents, forming pseudomorphs, the shape of which gives some indication of the nature of the replaced mineral. Augite has doubtless been replaced in this way, and the shape of some of the calcite-pseudomorphs point to olivine having been an original accessory constituent of the rocks. The feldspar (orthoclase) is surprisingly small in quantity, being confined to small microlites and interstitial patches in the groundmass, but the latter is generally so obscured by calcite-dust and iron-staining that even this can only be made out after dissolving away the carbonate of lime from the section with dilute acid. Chlorite is also present in patches and scattered fibres. In part this mineral is no doubt derived from the decomposition of the biotite, in part also from the augite. Magnetite is present in scattered granules.

"(3.) The intrusive felsites resemble the lavas in appearance, but have a more crystalline texture, the groundmass being distinctly microcrystalline. They may be described, therefore, as microgranites."

These intrusions may be inferred to be of post-Silurian age, for no petrological distinction can be drawn between the dykes or sills, whether of felsite or mica-trap, in the Lower Silurian and those in the newest Silurian strata existing in the neighbourhood. On the other hand we have strong evidence that they were pre-Carboniferous, for not only have we failed to find igneous rocks penetrating the Carboniferous strata, but in more than one case a dyke has been planed off, with the Silurian strata

in which it has been intruded, before the deposition of the Carboniferous Basement Conglomerate. The period separating the Silurian and Carboniferous epochs, however, was long, and we have reasons to suppose that the intrusions were not strictly contemporaneous, for the mica-trap dykes cut across the felsite-sills in a manner that can be explained only on the supposition that they were of later age. Considering their petrological affinity, we have some reason to suppose that the felsites (micro-granites) mark the same outburst of plutonic activity as the Shap granite, which we know also to have been of post-Silurian and pre-Carboniferous age,* while the mica-traps seem to have been injected along cracks, traversing both the felsites and the sedimentary rocks, at a later date and probably to a greater distance from the source of the melted material.

A glance at the map shows that the intrusions especially abound in the immediate neighbourhood of the domes of elevation which we have already noticed, and that away from such centres the felsites are either absent or appear only as narrow dykes. We know, moreover, that the domes had not only come into existence in pre-Carboniferous times, but that there had been time for the removal of the whole of the Upper Silurian rocks from many of them before the Carboniferous Basement Conglomerate was deposited. These facts suggest that the same plutonic energy which injected great sheets of felsite between or through the sedimentary strata was instrumental in elevating the strata into their existing domed form.

The Carboniferous Rocks repose naturally upon the upturned edges of the Silurian strata along the northern flanks of the Howgill Fells.† Towards the east of these hills, however, they are limited by a great fault, and instead of dipping away from the older rocks, are tilted up, and even inverted, along a belt of ground from a quarter to half a mile in width. The line of fault thus marked runs from the southern end of the Vale of Eden to near Ingleton, crossing Garsdale and Dent. We have elsewhere pointed out that the name of Pennine Fault, under which this line of fracture has been included with that which runs along the foot of the Pennine Range, is misleading, inasmuch as the former ranges about south-south-west with a downthrow east, while the latter runs south-east with a downthrow west. We accordingly proposed to use the name of the Dent Fault for the former, after the dale in which its effects are characteristically developed.‡ In the map now under description a length of about nine miles of the Dent Fault is included. Towards the north it is traced with difficulty, and probably dies out, a num-

* *Geology of the Country around Kendal, &c.* (Geol. Survey Memoir) 2nd ed., p. 34, 1888.

† *Geology of the Country around Kendal, &c.* (Geol. Survey Mem.), 2nd ed., pp. 20, 21, 25, and plate iii.

‡ *The Geology of the Country round Ingleborough, &c.* (Geol. Survey Memoir), pp. 83, 84, 1890.

ber of lesser faults crossing it at right angles, all with down throws to the south, contributing to this result. Southwards it becomes a well-defined line of crush, doubling back the Great Scar Limestone and at times the Yoredale Rocks, and throwing them face to face with the Silurian strata. Though the displacement effected by the fault is considerable, the compression undergone by the strata along its whole length forms its most marked characteristic. Its effects reach to about half a mile eastwards, the Carboniferous Rocks then assuming a nearly horizontal position, and extending with but little disturbance over the remainder of the area included in the map. Owing to a gentle easterly dip their lower members sink below the surface in the eastern part of the area. The Millstone Grit on the other hand, which occurs as small outliers only in the western part, forms extensive moorlands as it descends to a lower level eastwards.

According to the usual nomenclature the larger sub-divisions of the Carboniferous Rocks are as follows:—

Millstone Grit.

Yoredale Rocks (Upper Limestone Shale).

Great Scar, Carboniferous, or Mountain Limestone.

Lower Limestone Shale.

Basement Beds (red conglomerate).

The red conglomerate, the Old Red Sandstone of authors, is in reality the base of the Carboniferous Series, for in many parts of the north of England and Wales it dovetails with the overlying Carboniferous beds. It is, however, of quite local occurrence. It seems to have been deposited in hollows and the beds so formed to have been then overlapped by higher Carboniferous sandstones and shales. These latter, therefore, in the absence of the red conglomerate rest directly on the Silurian strata.

For the Lower Limestone Shales and Great Scar Limestone we adopt the classification given by Mr. Tiddeman in his description of the north-western part of the map (p. 78. *See also* *Geology of the Country around Kendal, &c.*, 1888, pp. 25–28 and 31–33), as the greater part of these beds only occur there. Owing to the number of sub-divisions in the Great Scar Limestone, it is somewhat doubtful in many places what ought to be considered its top. Professor Phillips selected the Gale Limestone and took the next limestone as the lowest of his Yoredale Series, calling it the Hardraw Limestone;* but this band cannot be distinguished from the Great Scar Limestone further south, for the intervening sandstones and shales die out in that direction.

* The term is misleading, for the hamlet of Hardraw stands on the limestone below the one meant; so we call it the Hardraw Scar Limestone, because it forms the top of the scar at the waterfall well known as Hardraw Force. Phillips called the next higher limestone the Simonside by mistake apparently for Simonstone, which is the name of a house, for there is no such place as Simonside. Accordingly we use the term Simonstone, but it is not a good name, as Simonstone does not stand on the limestone so called but on the beds between it and the Hardraw Scar Limestone.

The Middle Limestone consists of three divisions. The two lower members become distinct from the upper farther north where they are known as the "Single-post" and "Cockle-shell." Though generally thin, they are important aids to fixing horizons from their character and position. The "Single post" is so called because it usually occurs in a solid bed without partings. It has, moreover, a peculiar spotty appearance owing to the dissemination through it of a number of small calcite-crystals. The "Cockleshell" gets its name from the number of *Producti* which characterise it.

The Impure, Productal Limestone of Phillips, though thin, serves to fix horizons by its marked character and position close to the top of the Middle Limestone. It becomes thicker northward where it is known to miners as the "Five-Yards Limestone" from its more usual thickness. In Swaledale it is generally called by miners the "Third Set," though in some places it is called the "Fourth Set," which in reality it is, reckoning down from the Main Limestone. About Garsdale it is known locally as the "Horseshoe" or the "Cockle-shell"; but when so called it must not be confounded with the limestone better known by that name, described above, which lies lower in the series.

The next limestone, known as the "Three-Yards," in the north of England, is of no importance in Wensleydale and of very little in Swaledale, where, in fact it is generally omitted by miners in reckoning the beds or "sets" as they are called. The Underset and Main Limestones are so thick and pure that they are in general unmistakable. There is often a cherty bed on or a little above the Underset known as the Underset Chert. In Swaledale the Main Limestone is immediately overlain by a cherty series known as the Main Chert and the Black and Red Beds. These pass westward and northward into a series of grits, sandstones, and shales, known in the north as the "coal-sills," capped by a bed of chert or limestone called the Little Limestone. The term "coal-sills" is used, because in the typical area where the term was first employed, the sandstones of the series often are the sills to coal-seams.

The "Ten-Fathom Grit" of the Swaledale miners consists generally of flags. It often has its top marked with *Cauda galli* and of a gannister character. It very generally occurs in two divisions with a coal-seam and a thin "Crow" limestone between the two members.

The highest bed of the Yoredale Series in our Table is generally a tough, gannister-like sandstone. It is constant both in occurrence and character over the greater part, though not over the whole of the area of the map. It is also often double with a coal between the two beds of sandstone. From its position with reference to the thin fossiliferous beds in the shale below, as well as from its character, it is supposed to be identical with the bed known in the north as the "Grindstone," which forms

the great grit-scar near the top of Cross Fell. Its horizon is at or near the base of the pebbly grit of Ingleborough.

Owing to the low dip that prevails generally in the Carboniferous area east of the Dent Faults the higher hills are exclusively composed of Millstone Grit, which thus forms most of the wild moorland of that area, while the Yoredale Beds and Carboniferous Limestone are nearly confined to the sides and bottoms of the valleys.

Lithologically the Millstone Grit series consists of a great thickness of alternating beds of shale and sandstone of varying character vertically, but often persistently similar for some distance on the same horizon. The sandy beds vary much in coarseness, hardness, and colour, and the shales occur as almost unbedded clays or as finely laminated deposits, and sometimes contain animal fossils and sometimes vegetable, the former generally in clayey or calcareous shale, the latter usually in sandy shale. Coals are not uncommon; limestones, though rare, are occasionally met with.

It is, however, a disputed point what is the best line of division to take between Yoredale Rocks and the Millstone Grit. Very different lines have been taken by different persons in different places. This subject will be fully treated in the detailed description of the rocks, but we will give here a summary of the results arrived at. Phillips took as the top of his Yoredale series the top of the Main Limestone, and we did the same in our published maps of Wharfedale and Coverdale. Other geologists have taken the base of the Ingleborough Grit as the base of the Millstone Grit. Now, in trying to carry on this line we find that the characteristic pebbly part of that grit dies out entirely. But there is generally north of Wensleydale the gannister-like bed (the supposed "grindstone") at or near the base of the pebbly grit; in fact some sections in Swaledale seem to show that the gannister and pebbly grit represent and replace each other. This gannister-like rock we can trace fairly well on the whole into Westmoreland, so that were we to take this as the base of the Millstone Grit we should be able to keep to one horizon so far, instead of having to run our base-line athwart the beds on the dying out of the pebbly grit, as we must do if we put the gannister into the Yoredale Series.

On the other hand, in the North of England the "grindstone" has always been taken as the topmost bed of the limestone-shales, and the base of the Millstone Grit has been put at the base of the sandstone next above the grindstone. Moreover, it would probably be a matter of great uncertainty tracing the bed along Stainmoor.

It will be seen that the chief difficulty arises from the changeable and inconstant character of sandstone-beds. A limestone-top is always the best line of division to take when possible; for limestones, even when thin, persist over wide areas; and their tops, from being marked by pot-holes, can often be distinctly traced even when the bed itself is not seen.

Now, the top of the cherty series overlying the Main Limestone is definite enough (being succeeded by shale and the Ten-Fathom Grit); and the Little Limestone on the top of the "coal-sills" is very persistent, and consequently affords an excellent horizon; and as the coal-sills and correlative cherty series thin southward till they die out altogether or become a mere capping of chert about a foot thick on the Main Limestone, were we to take the Little Limestone as the top of the Yoredale Series (making all above it Millstone Grit), we should have a line of division which we could carry on, and it would also practically be the same line as that taken by Professor Phillips and by ourselves in Wharfedale. But, on the other hand, the limestone does not form the natural top of the limestone-series of Northumberland, but lies below strata which in every respect should be associated with the Yoredale Series rather than with the Millstone Grit.

Confining our attention to the beds which are recognised by everybody as belonging to the Millstone Grit Series, we may divide the whole into five groups of sandstone separated by shale, the Ingleborough Grit forming the lowest group. This and the three groups above it are considered as equivalent to the Kinder Scout Grit.

Towards the north the map includes a portion of the Permian Rocks of the Vale of Eden. These strata, consisting of red sandstone and a brecciated conglomerate known as Brockram, rest unconformably on the Lower Carboniferous Rocks, in the present instance partly upon the Yoredale Series and partly on the Great Scar Limestone. They are themselves overlapped by the St. Bees Sandstone, a small area of which falls within the limits of the map.

In the landscape the Silurian Rocks are marked by their softly-flowing, rounded contours; the Carboniferous give a tableland in a state of disintegration where hard and soft alternations thrust themselves into notice by abundance of scarps and terraces, only in some parts barely concealed by a veil of Drift.

The features to which the Yoredale Rocks give rise on the hillsides form an important element in the landscape, besides varying much the character of the ground for pastoral purposes. The limestones, where thick, give a short, sweet pasture, unless they are masked by *débris* from shales or sandstones of the overlying members. They may be often traced on the hillsides at a distance by the long lines of "pots" or swallow-holes which are dotted along their upper surface, and the corresponding springs which issue from their base. The smaller limestones, on the other hand, often require careful search to find; small isolated swallow-holes will sometimes betray their presence when they are nowhere visible at the surface, but they are often completely masked. The Permian and Triassic Rocks, being mostly soft and lying on low ground, gives hardly any characteristic feature at all, their surface being well stippled over with abundant mounds of Glacial Drift or covered over with flat spreads of alluvial wash.

CHAPTER II.—LOWER SILURIAN ROCKS.

CONISTON LIMESTONE SERIES WITH CONTEMPORANEOUS AND
INTRUSIVE IGNEOUS ROCKS.

This series includes the following sub-divisions :—

Ashgill Shales.

Volcanic rocks (felsites and ashes), dying away southwards.

Black limestone and shale.

The lowest beds seen, the Coniston Limestone proper, consist of black or dark-blue limestones, more or less impure, and varied by bands or nodules of impure chert, alternating with dark calcareous shale which splits up by a rough cleavage into irregular prisms and splinters. As the series is followed upward the shale predominates, while the limestones are represented only by calcareous nodules and finally disappear, so that there is a passage up into the Ashgill Shales. In the northern part of the district, however, the lower sub-division passes up into well-bedded felspathic ashes associated with felsitic lava-flows, which in their turn pass up into the Ashgill Shales. The base of the Coniston Limestone is nowhere reached in the inliers about to be described ; the greatest thickness of Ashgill Shales occurs in Fairy Gill where it may amount to 850 feet. The Volcanic Series reaches a thickness of 60 or 70 feet, where most fully developed. A somewhat similar series, it may be noted, occurs in the Coniston Limestone between Shap and Windermere,* between Coniston and the sea, and near Appleby, while grits resembling ash-beds occur, according to Professor Hughes, just above the Coniston Limestone in the Craven area.† On the series, as it occurs in the area now under consideration, Dr. Hatch furnishes the following notes :—

“The contemporaneous felsites occur in thin beds (flows) among elastic rocks of volcanic origin. They are grey and reddish rocks, consisting of porphyritic crystals of quartz and felspar imbedded in a compact matrix, or of compact and homogeneous material without porphyritic crystals. In their present state they represent altered rhyolites. The porphyritic felspar is kaolinized and calcified, and the groundmass, originally glassy, has assumed a felsitic or cryptocrystalline character.

“The volcanic tuffs are similar in appearance to the compact felsites, but they have a laminated and sometimes banded structure. Under the microscope they often present, when composed of very fine material, a cryptocrystalline appearance similar to that of the felsites ; but generally the presence of distinct fragments enables them to be identified as elastic rocks.”

* Geology of the Country around Kendal, &c. (Memoirs Geol. Survey), 2nd ed., pp. 7-10, 1888.

† *Geol. Mag.*, vol. iv., p. 354, 1867.

Five distinct exposures of this series fall within the limits of this map. The southernmost lies on the south side of Hebblethwaite Gill, in a tributary of which black shales, believed to be Ashgill Shales, rise from beneath the Pale Slates exposed in the main stream. The shales are faulted against Coniston Flags towards the west, and are quickly overspread by Carboniferous Basement Beds on the east, so that the Coniston Limestone proper is not exposed.

Cross Haw to Taiths.

About a mile to the north the series rises again from beneath the Coniston Flags and extends some two miles along the Dent fault. On the north, west, and south sides of this inlier the Stockdale Shales rest naturally upon the Ashgill Shales, but towards the east the area is bounded by the fault, the Stockdale beds, where present, or the Carboniferous Limestone, being thrown down against the Coniston Limestone. Several gills intersect the margin of the area, and expose numerous dykes of felsite and mica-trap, and the great intrusive sill of felsite of Taiths Beck (Fig. 10, p. 58). No contemporaneous rocks have been noticed in this exposure of the Coniston Limestone Series.

At the south end of the exposure Cross Haw Beck gives a poor section of the Pale Slates with two intrusive masses of felsite, and above the northernmost mass a tributary stream from Marsh Yeat shows Coniston Limestone traversed by a dyke of mica-trap. About 100 yards farther east the dyke, still in Coniston Limestone, crosses the main stream, while between it and the felsite, black shales, comparable to the Dufton Mudstones, crop out. The stream then, under the name of Whinny Gill, flows for about 300 yards over nearly vertical Coniston Limestone, partly along the strike, but passing obliquely on to Pale Slates with two dykes, and eventually at High Pasture Wood on to the lower beds of the Coniston Flags (pp. 32, 33), before it crosses the Dent Fault. It is certain that the sequence here is incomplete, for there is not sufficient room for the Graptolitic Mudstones and the Ashgill Shales to crop out, even supposing them to be vertical, but whether their absence is due to a fault, or to the squeezing out of the more plastic strata, there is not sufficient evidence to show. The complication is further increased by the fact that the more northern of the felsites crosses obliquely from the Pale Slates to the upper part of the Coniston Limestone. Two hundred yards west of Marsh Yeat the Graptolitic Mudstones crop out at a fork in a lane, while a little further south in the same lane one of the sheets of felsite comes into view.

In the next gill, that of Birks Wood, we cross Pale Slates and Graptolitic Mudstones and enter upon the Ashgill Shales at 130 yards from the high road, and two or three yards west of a mica trap dyke. Fifty yards further up the gill thick black

limestone rises from beneath the shales. Birks Field Beck lies 200 yards further north. At 60 yards from the road it crosses the junction of the Graptolitic Mudstones and the Ashgill Shales, the latter containing nearly at their top a thin band of grit, to which allusion will be made subsequently (p. 25). Fifty yards further up, the stream cuts through a mica-trap dyke, presumably the same as that seen in Birks Wood, and thence eastwards passes over shale with bands of limestone in which four more dykes occur. Other small watercourses further north along the hill-side expose shale with bands of dark limestone, and in one case a mass of intrusive felsite of unknown extent. The dip in all these gills ranges from 35° to 55° in a general westerly direction.

Taiths Gill gives an excellent section of the Coniston Limestone, and of a great sill of felsite, and dykes of mica-trap (Catalogue No. 1,470). Near the boundary of the Pale Slates there are some large blocks of mica-traps on the south side of the stream, but it is impossible to say whether they are *in situ* or whether they are derived from a dyke which traverses the Pale Slates a little west of the line of junction. About 30 yards further east felsite occurs in the bed and on the south side of the gill, but in a very short distance ends off sharply against black shale (Ashgill Shales), and seems to be thrown back to the east. Almost immediately it again crosses to the west side of the brook, but soon turns slightly to the east, so that black shale forms one side, and felsite the other of the water-course. This continues until a north and south fault once more throws back the felsite, and black shale occupies both sides of the channel. At a bend in the stream the felsite again crosses to the north-west side and extends as far as a mica-trap dyke (Catalogue No. 1,480) which ranges in a N. 28° W. direction. There is also a shift along this dyke, for the felsite on the north-east side of the dyke is now seen on the south side only of the brook. A tongue of felsite projects across the stream from the main mass, which once more crosses to the north-west of the stream, and continues for a distance of about 100 yards to the next bend. Here it is again shifted southwards; and from this place eastwards as far as Taiths, black shale with bands of limestone (Coniston Limestone), dipping west of north at from 30° to 45° and turning to north and east of north at Taiths, is well exposed.

The Coniston Limestone is here traversed by several dykes. At Gill Wood a trap-dyke runs N. 5° W. East of Intack Wood a mica-trap dyke, from 8 to 10 feet wide, runs nearly north and south, and hades to the west. Eight chains farther east another dyke of mica-trap ranges nearly parallel to the last-mentioned. Between these two dykes a small boss of felsite comes up through black shale.

Specimens of the great felsite-sill of Taiths Beck, collected at the bridge near Taiths, and of one of the mica-trap dykes, are thus described by Dr. Hatch:—

“(Catalogue No 1,470.) This is a light-grey rock spotted white with felspar-crystals. Under the microscope it is seen to consist of grains and

crystals of orthoclase, and, more rarely, irregular blebs of quartz, imbedded in a fine cryptocrystalline groundmass of quartz and felspar, together with shreds of muscovite. The orthoclase-crystals are much kaolinized, but sometimes show Carlsbad twinning.

"(Catalogue No. 1,480), a dyke of mica-trap in Taiths Gill, 200 yards north of Fox Hole Rigg. A cream-coloured rock with disseminated glistening flakes of mica. Dark mica (biotite), sometimes in regular six-sided plates, sometimes in ragged patches and blades, imbedded in a pale-brown calcareous groundmass with a small quantity of interstitial felspar. Magnetite in minute granules. Structure obscured by calcite-dust."

It is difficult to trace the actual base of the sill of felsite described above, but the exposures in the small valleys east of Fox Hole Rigg, on the south side of Taiths Gill, show that it attains a considerable thickness. At Taiths the gill turns sharply to the south and cuts a deep gorge in the Coniston Limestone Series and across the felsite, which here breaks across the bedding of the black shale in contact with it. South of the felsite the dip varies in direction from east to north, and in amount from 15° to 30° . Near the south end of Taiths Beck Wood a fault crosses in a direction S. 25° W., with a hade to the north-west, and on its south side the strata dip to north-east, but further southwards are inclined to the south-east at angles ranging from 60° to 65° , and so continue as far as some small dykes of felsite near the fault which brings in the Pale Slates. Between the dykes and this fault the dip is north-west at 50° to 65° . The section forming Fig. 10 (p. 58) crosses Taiths Beck at the point where these dykes are exposed. It shows also the great felsite-sill, cut across, as we presume it to be, by one of the vertical mica-trap dykes seen in the river below Taiths.

The Ashgill Shales are exposed in Splender Gill, Bluecaster Gill, Fairy Gill,* and at various places within the triangular space between the Dent Fault and Bluecaster. In Fairy Gill they are cut through by a mica-trap dyke about 4 feet wide, trending N. 10° W.

The Rawthey, Sally Beck, and Wandale.

The next inlier of the Coniston Limestone Series to be described extends from the Rawthey to Sprintgill, and occupies Wandale and the valley of Sally Beck. On the south side of the inlier the series is thrown against Graptolitic Mudstones by a fault which is well exposed in the banks of the river a quarter of a mile west of Rawthey Bridge. Towards the west and north it dips naturally under the Stockdale Shales, and towards the east it is limited by the Dent Fault.

The section in the Rawthey discloses black shale and limestone, traversed by three dykes of mica-trap, the middle one of which is thus described by Dr. Hatch:—

"(Catalogue No. 1,478.) Dyke 300 yards west of Rawthey Bridge. Reddish-brown rock with large flakes of lustrous brown mica. Effervesces

* From this gill the type-specimens of *Strophomena siluriana*, described by Davidson (*Pal. Soc., Sil. Brach.* 1864-71, p. 333) were collected by the Rev. H. G. Day and Professor Hughes.

with acid. Under the microscope plates and blades of brown mica (biotite) imbedded in a reddish-brown groundmass, consisting chiefly of minute felspar-microlites, but obscured by staining of ferric oxide. Small calcareous pseudomorphs after augite (?). Minute scattered granules of magnetite. Cavities filled with calcite and lined with chlorite."

The middle dyke is shifted six feet on the south side of the channel; the easternmost dyke coincides with the bedding on the south side, but on the north apparently ends off against a joint in black shale. The dip ranges from nearly north to west, and similar strata crop out in Sally Beck as far north as Bridge, where a sheet of felsite crosses the stream. But from this point thin-bedded fissile shales, of a grey tint, but weathering brown, extend along the east side of the valley as far as Foggygill, and are well exposed near Murthwaite and at Sally Beck. The dip, as far as it can be determined in such cleaved rocks, coincides with that of the limestone in Sally Beck, and these grey shales may be considered to belong to the Ashgill Shales, to which they bear a close resemblance. They are probably faulted against the limestone of Sally Beck near the felsite mentioned above. At Murthwaite, *Actinocrinus*, *Petraia*, *Encrinurus*, *Trinucleus*, *Leptaena*, *Orthis*, and *Strophomena* were noted by Professor Hughes. North of Foggygill limestone of the usual Coniston type rises from beneath the Ashgill Shales of Murthwaite with a dip to the north-west of 25° to 50°. It is exposed both in Sally Beck, where it contains two small dykes of mica-trap, and in a ravine 100 yards south of Sprintgill, where it is traversed by a vesicular dyke of andesite, described by Dr. Hatch as follows:—

"(Catalogue No. 1,485.) This rock is composed of porphyritic lath-shaped felspars much altered and replaced by calcite, imbedded in a dark-coloured groundmass full of minute spicules of felspar and scattered granules of magnetite. Unaltered augite is not visible in the section. Vesicles infilled with chlorite."

The strike of the Ashgill Shales of Murthwaite, would, if continued, carry them across the ridge into a part of Wandale, where Coniston Limestone alone is exposed, and where, moreover, the dip is nearly at right angles to that which prevails at Murthwaite. There must therefore be a fault somewhere along the ridge, as shown on the map, but there are no sections to show its exact position.

In Wandale we find exposed for the first time the contemporaneous Volcanic Rocks in the Coniston Limestone Series, to which allusion has already been made. Near the foot of the dale the strata dip southwards at high angles, but sweep round so as to strike along the west side of the dale for about half a mile to Odd Gill, where the best exposures occur, and thence strike eastwards towards Sprintgill. Several sills of felsite penetrate both the limestone and the Ashgill Shales, and seem also to break across the contemporaneous Volcanic Series, causing

great complication. In which class the felsite of Sally Beck should be placed remains doubtful from the incompleteness of the section.

In ascending Wandale Beck we meet, just above the road to Murthwaite, hard, dark, imperfectly cleaved shales, presumably the Ashgill Shales, which occupy the stream for 200 yards. About 26 yards south of a small wood on the west bank pink close-grained felsite crosses, and upon it lies a hard grey felspathic rock, which resembles certain banded rocks, presently to be described as presumably volcanic ash. Higher up the stream, but geologically below the felsite, similar grey felspathic rock, with a second band of felsite, continues as far as the centre of the wood, from which point the stream flows over felsite for about 65 yards. We then come upon hard dark shales with scattered cubes of iron-pyrites, and shales with bands and concretions of limestone, the Coniston Limestone proper, which with a general north-westerly dip form the channel of the beck as far as Odd Gill. From the absence of volcanic ash we suppose the last-mentioned felsite to be intrusive.

On ascending the numerous streamlets which drain the western slopes of Wandale, we find no difficulty in tracing the felsite associated with the supposed volcanic ash to a point only 300 yards short of Odd Gill where we obtain evidence of its being a contemporaneous outburst, while, higher up in the hill-side, a series of exposures shows an intrusive sill of felsite, corresponding in the absence of the supposed ash to the thick felsite already mentioned, but differing from it in lying above the ashy series instead of below as in the beck. The intrusive rock must be supposed, therefore, to break across the ashy series somewhere in the small wood, or just above it, but at that point the exposures are too scanty to enable us to say with certainty what takes place. Taking the streamlets in order from south to north we find the following succession. In the first streamlet north of the wood, dark shale and limestone dipping N. 28° W. at 67°, and passing up into grey felspathic ash near the first fence, then a felsite followed by more ash, and lastly an intrusive sill of felsite. The next streamlet shows the same sequence, with the addition of a second intrusive sheet of felsite higher up the hillside. The third streamlet exposes the contemporaneous felsite and ash, and the thick sill next above it. In the fourth streamlet these two reappear, with a thin band of intrusive felsite between them, while above them in the hill-side there crop out Ashgill Shales weathering into prism-shaped fragments and containing *Orthis hirnantensis*. At this point the contemporaneous series descends close to the west bank of Wandale Beck, and runs under Drift, still, however, showing through at intervals.

At the mouth of Odd Gill the contemporaneous series crosses Wandale Beck, with a northerly dip of 20° to 35°, while 100 yards further up a felsite, doubtless the thick sill we have been

tracing, appears in the west bank of the beck for about 40 yards. Above this again black shales with iron-pyrites are seen in the east bank, but the rest of the section is obscure. Odd Gill gives a good exposure of beds of ash which lie above and below a contemporaneous felsite lava-flow. The volcanic rocks form a little cliff for a few yards south from the junction of Odd Gill and Wandale Beck. From below it rises a grey and yellowish felspathic rock, much resembling felsite, though with a more hackly fracture, and showing distinct bedding and even lamination. Above it lies a similar rock, but more distinctly shaly and with remarkably regular lamination. In these shaly ashes, as we suppose them to be, runs a twelve-inch band of bluish vesicular felsite, which we identify as a small lava-flow, and which is thus described by Dr. Hatch:—

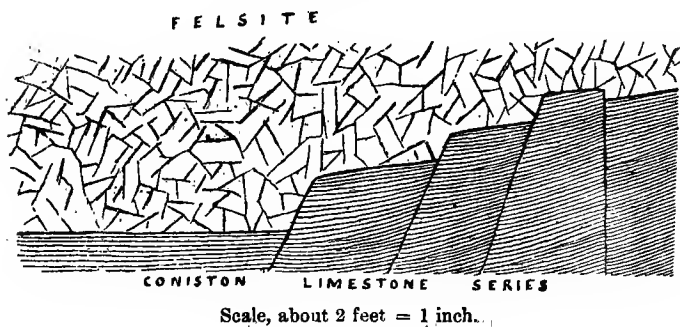
“(Catalogue No. 1,460.) This is a dark-grey felsite with crystals of light-coloured felspar (much calcified) and blebs of glassy quartz, imbedded in a compact flinty groundmass. This groundmass examined under the microscope appears pale-brown and fibrous, and exerts but little influence on polarized light.”

Further up the gill the laminated ashes pass up into a hard dark rock, often crowded with little cubes of iron-pyrites, and this into shale with limestone of the usual character. One hundred yards from its mouth the gill crosses the base of the intrusive felsite and gives an interesting section of a number of little faults by which it is displaced (Fig. 1). The felsite has

Fig. 1.

Section in Odd Gill, Wandale, shewing a felsitic sill resting on Coniston Limestone, displaced by small faults.

By R. Russell.



been intruded along the bedding in the form of a sill, and rests upon a slightly uneven surface of a bedding-plane, the small faults alluded to traversing the junction of the two rocks in a northerly direction, and repeatedly shifting it from a few inches to two or three feet down to the west. The felsite

crosses the gill obliquely and forms the bed of the stream as far as the boundary-fence of the fell, where it is succeeded by shale (Ashgill Shales). It there disappears under the Drift of Murthwaite Rigg. One hundred yards west of Sprintgill felsite is exposed which is of close texture, pink, and associated with shale much like the contemporaneous ash, but we are left in doubt, from the limited extent of the section, whether to connect it with contemporaneous series. In the lane, and within a few yards of the base of the felsite, shale with limestone (Coniston Limestone) crops out.

One hundred and fifty yards south-east of Wandale there is a small exposure of diabase, intrusive in Ashgill Shales.

Backside Beck and Cautley.

On crossing the Coniston Flags of Wandale Hill we enter the inlier of the Coniston Limestone Series which occupies the valley of Backside Beck. This dale resembles Wandale in structure. Towards the south-west it is bounded by a fault with a downthrow to the north-east, and towards the east by the Wandale Hill Fault, which runs roughly parallel to the Dent Fault, and, like it, throws the strata down eastwards. On its west and north sides the Coniston Limestone passes naturally under the Upper Silurian rocks, as in Wandale. The volcanic rocks herein exposed closely resemble those of Wandale, except in there being a larger number of felsitic intrusions.

For rather more than half a mile from its mouth the beck flows over Coniston Grits and Flags (pp. 35-37). It then crosses the Wandale Hill Fault, which is marked by a belt of brecciated limestone, shale, and slate, with ramifying threads of calcite, and exposes to view a mass of felsite intrusive in limestone. From this point upwards, as far as its division into Spengill and Stockless Gill, the beck flows over the Coniston Limestone Series. The effect of the fault here, therefore, is to cut out the Coniston Flags, the Stockdale Shales, the Ashgill Shales, and a portion of the Coniston Limestone; but further north it merely shifts the Pale Slates against Coniston Flags. Fault-breccia with calcite occurs on Wandale Hill also, at the intersection of the fault with the western boundary-fence.

Continuing up the beck for 150 yards over crushed limestone and shale, we see a dyke of mica-trap running S. 28° E. on its west bank, and then cross shale and limestone, gently undulating, but with a general north-north-westerly dip of 20° to 25°. The mica-trap is thus described by Dr. Hatch:—

“(Catalogue No. 1,474). Dark-grey rock with dispersed specks of mica. Under the microscope abundant brown mica (biotite) in blades and patches, imbedded in a chloritic and calcareous groundmass. Isolated calcareous and chloritic pseudomorphs after a well-crystallised mineral having the form of augite are also present.”*

* This rock was described by Prof. Bonney and Mr. Houghton, and termed by them a minette-felsite. *Quart. Journ. Geol. Soc.* vol. xxxv. p. 178. 1879.

The limestones increase in thickness as we proceed, and form a series of small waterfalls. Above the next stream which enters from the west, and about 30 yards above a ruined footbridge, a sill of whitish felsite, with a dyke of mica-trap at its base, crosses the stream, and, at the fence which comes down from a barn on the east side of the dale, passes under limestone with thin partings of shale, and but little altered. The dyke at the base of the felsite has been examined by Dr. Hatch, who makes the following notes:—

“(Catalogue No. 1,481). Black compact rock, speckled over with glittering flakes of mica. Effervesces with acid. Microscopic appearance similar to that of No. 1,475 (p. 26) but finer-grained.”

Both the felsite and the dyke seem to follow the bedding of the rocks into which they have been injected, but on returning to the streamlet on the east side we find the dyke penetrating the felsite, and not, as in the beck, running between it and the limestone. In this same streamlet a second sheet of felsite is exposed, which can be followed down to the main beck below Backside Farmhouse. Below it, in the beck, lie dark shales with bands of limestone, dipping north-westward at 5° to 10° , and becoming harder and more massive immediately below its base, where also they contain many crystals of iron-pyrites. Just above the first felsite noted *Phacops Brongniarti* occurs in the limestone.* The second felsite is white, and presents a false appearance of bedding, as is commonly the case. It forms the channel of the beck for a few yards, but then mounts to the top of the west bank, the limestone abutting against it along a line running nearly west-north-west, in a manner that may be due to the intrusive rock having broken across the limestone during injection, or, as has been assumed on the map, merely to a small fault. The two felsite-sills described above are both visible on the east side of the dale also, in the streamlets which descend the hillside near and south of Backside Farm. It will be noticed that, though intrusive, they follow the bedding for a considerable distance and thus are correctly described by the term sills.

About 18 yards higher up the stream an irregular felsite-dyke, about $3\frac{1}{2}$ feet in width, breaks across the strata in a S. 35° E. direction, and immediately north of it the dip changes to a general south-westerly direction at 10° to 20° , sweeping round, however, at Watley Gill to a westward direction. The strata consist of dark shales with bands and concretions of limestone, and a few yards below that gill are traversed by a small fault running a little south of west with a downthrow to the north.

Above Watley Gill a number of intrusive felsites make their appearance. In their behaviour with respect to the limestone,

* At Appleby, according to Mr. Marr, the horizon of this fossil lies above the contemporaneous volcanic series. Here it seems to occur at a considerable distance below that series.

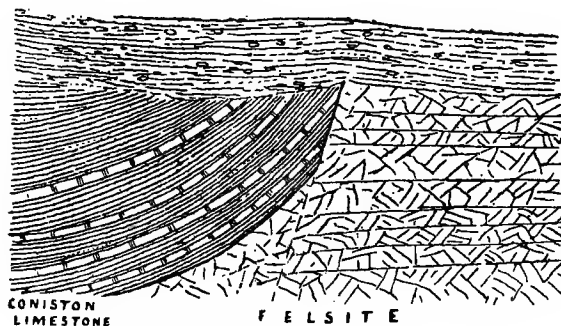
and in their general character, they resemble those we have already described. They occur, too, at about the same horizon in the limestone-series, and the change in the dip, combined with the faults, would account for their reappearance. But, as will be seen subsequently, the sills are inconstant and possess no marked characters by which any one can be distinguished from another, whether it is intrusive in Coniston Flags, Pale Slates, or Coniston Limestone. The actual continuity of the sills in the upper part of Backside Beck with those already described is purely a matter of speculation, and of no particular consequence.

The first felsite we come to occurs, with a thickness of 6 feet, on the east side of the beck about 80 yards above Watley Gill, and on the west bank a little higher up, the two exposures being connected by a narrow band along a joint in the bed of the stream. It abuts on the north, along a line running nearly north-west, against shale with bands of limestone dipping south-westwards at 25° to 30° . The next sill of felsite commences 100 yards above Watley Gill, and occupies the beck for about 110 yards. At its southern boundary (its upper surface, the dip being here south-west and rather down the stream) it ends abruptly as though by a fault (Fig. 2).

Fig. 2.

Section in Backside Beck, shewing the Coniston Limestone Series faulted, as supposed, against a felsitic sill.

By R. Russell.



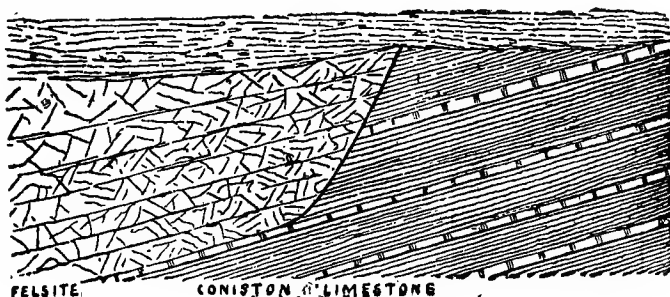
Scale, about 4 feet = 1 inch.

Towards the north its base, after running a few feet along the west bank parallel to the dip, rises sharply up, so as to abut against shale with bands of limestone (Fig 3), possibly in consequence of a slight shift, but no distinct break can be detected in the brook-channel.

Fig. 3.

Section in Backside Beck, shewing the base of the felsite of Fig. 2.

By R. Russell.



Scale, about 4 feet = 1 inch.

The width of outcrop of this felsite may be attributed to the low dip of the strata rather than to an unusual thickness. It does not reappear on the west side of the dale, and is a few feet thick only in the streamlets on the east side. Five of these streamlets descend the slope north of Backside Farm. In the first, which runs 100 yards north of the farm, shale and limestone only are seen up to the boundary-wall of the fell, above which is a felsite, probably a sill, but much obscured by talus. The next streamlet rises high up on Wandale Hill; in its upper parts it cuts a deep ravine in Ashgill Shales with two dykes of mica-trap. Near the boundary-wall there are fragments of felsite, but none of that rock seen in place; below the wall the stream traverses shale and limestone, and is crossed by felsite no less than five times before its termination. The third streamlet flows over shale and limestone and four distinct sills of felsite; the fourth enters the beck at the southern margin of the wide felsite already mentioned. Higher up it crosses a second sill of felsite in limestone. The fifth rises just above a felsite and exposes below it a small shoulder of rock resembling felspathic ash, and supposed in consequence to belong to the contemporaneous series. Lower down the stream crosses a felsite-sill, and then flows over limestone to its termination. In spite of these numerous small exposures it has proved an impossible task to join up the various sills of felsite from gill to gill. They clearly die out, wedge in, and even ramify among the sedimentary beds.

The last-mentioned streamlet leads us down to the beck about 80 yards above the wide exposure of felsite already noted. Just above the felsite a mica-trap dyke cuts through the strata on the east bank, and near the same spot the dip changes from south-west to nearly due north, and so continues, except in some

undulations, to the head of the dale, the stream crossing a nearly continuous ascending section. For about 170 yards above the felsite it exposes shale with limestone, the bands of the latter rock becoming thinner and more nodular upwards until they are represented only by calcareous concretions in shale. These strata pass up into a hard banded black rock, perhaps a fine volcanic ash, at the top of which occurs a thin band of tuff, containing many fragments up to the size of a marble, and some large lumps of blue felsite. On the tuff rests a close-textured felsite (Catalogue No. 1,463), about 30 feet thick, pink above, but becoming yellowish below, which we assume to have been a submarine lava-flow. The felsite is succeeded by hard yellow or grey shaly rock much resembling felsite in hand-specimens, but clearly stratified and even laminated, and therefore presumably a felsitic ash (Catalogue No. 1,464). The laminated ash is about 15 feet thick and contains a band of bluish vesicular felsite (Catalogue No. 1,462), 10 inches thick and precisely similar to the thin band in the contemporaneous series in Wandale (p. 19). In the upper part of the ash-beds there appear lines of calcareous concretions as though the condition of the seabottom was gradually becoming normal after the volcanic outburst. No fossils, however, have been found in them. Dr. Hatch furnishes the following notes on the felsites and ashes referred to above:—

“(Catalogue No. 1,463). A red homogeneous and compact felsite. In this rock there are no individualised constituents, and the compact felsitic material is almost isotropic between crossed nicols.

“(Catalogue No. 1,464). A compact banded grey rock.

“(Catalogue No. 1,462). This rock consists of irregular porphyritic grains of quartz imbedded in a cryptocrystalline or felsitic groundmass. Infilled vesicles. Individualised felspar is not present.”

The pink felsite occupies the stream from a point about 150 yards north of the northernmost wall. It thence gradually dips northwards until the overlying ash descends to the level of the water, but it should be noticed that a small fault follows the bed of the stream for some yards and shifts the whole series about 20 feet down to the west causing an apparent want of correspondence in the two banks. A few yards further on a larger fault crosses the beck obliquely in a north-north-westerly direction, with a considerable upthrow to the east, so that the volcanic series, after dipping down below the surface, is brought up again, and a repetition of the section already noted is presented in the next 100 yards.

The felspathic ashes which overlie the felsite pass up into hard grey slaty rocks with a few bands of limestone containing *Trinucleus seticornis* in the upper part, and these into shales, which split up into pencil-shaped splinters. Here a pink felsite of close texture crosses the stream, dipping with the beds; but whether a sill or a contemporaneous lava-flow there is nothing definite to show. Presumably, however, it is intrusive, for it is followed, still in ascending order, by hard rock of flinty texture,

probably hardened shale, and by splintery shales and mudstones (Ashgill Shales), which occupy the beck to a point 80 yards above its division into Spengill and Stockless Gill, where the Graptolitic Mudstones commence (pp. 28-30). About 150 yards south of the forking of the beck a mica trap dyke cuts through the shales in a direction N. 42° W. The rock is thus described by Dr. Hatch:—

“(Catalogue No. 1,471). Fine-grained grey rock, speckled over with flakes of mica. Effervesces with acid. Lath-shaped crystals and blades of brown mica (biotite) imbedded in a semi-opaque brown groundmass, in which, with the exception of a few specks of magnetite, nothing can be clearly distinguished. This is due to the abundant presence of calcite-dust and to staining with ferric oxide. Calcite-pseudomorphs. Cavities filled with calcite.”*

A few yards below the forking of the beck and on the west bank a hard calcareous grit was noted by Professor Hughes in the Ashgill Shales. It has yielded *Cornulites*, *Orthis protensa*, Sow., *O. biforata*, Schloth, *Strophomena siluriana*, Dav., and *Meristella crassa*, Sow. (?), according to Mr. Marr and Dr. Nicholson, who remark: “The first four of these are found in the Ashgill Shales. This grit-land is succeeded by several feet of leaden-blue, cleaved, non-laminated mudstones, with abundance of *Phyllopora Hisingeri*, M'Coy, and *Myelodactylus*, sp. They are quite similar to the Ashgill Shales of other areas, and we believe that both these shales and the grit are referable to that horizon.”†

A grit occupies a corresponding position in Taiths Gill also, just above where the footpath from Lower Backside crosses to Fox Hole Rigg. There it occurs in the form of a calcareous pyritous conglomerate about 6 feet in thickness, and chiefly composed of fragments of Coniston Limestone and shale in a dark-grey calcareous matrix. This conglomerate can be traced a few hundred yards up the beck with a dip corresponding to that of the adjoining Upper Silurian Rocks. The occurrence of a similar grit in the Ashgill Shales of Birk's Field Beck has already been noted (p. 15).

Watley Gill, which drains the saddle between the Coniston Grit hills of Kensgriff and Yarlside, forms the only remaining section in the Backside Valley. Near its junction with Backside Beck it exposes shale with bands of limestone dipping westwards at gentle angles, and 130 yards west of the junction crosses a dyke of mica-trap ranging N. 37° W., on which the following observations are made by Dr. Hatch:—

“(Catalogue No. 1,482). Black compact rock; speckled over with glittering flakes of mica. Effervesces with acid. Under the microscope, plates and blades of brown mica (biotite), small patches of colourless felspar. Greenish-yellow groundmass with minute granules of magnetite. Mica penetrated by needles of apatite.”‡

* This seems to be the dyke described by Prof. Bonney and Mr. Houghton as kersantite-porphyrine in *Quart. Journ. Geol. Soc.* vol. xxxv. p. 178. 1879.

† *Quart. Journ. Geol. Soc.*, vol. xlv, p. 760. 1888.

‡ This is probably the dyke termed a kersantite-porphyrine from “Wattle” Gill, Westerdale, by Prof. Bonney and Mr. Houghton in the *Quart. Journ. Geol. Soc.* vol. xxxv. p. 178. 1879.

Above the dyke it traverses laminated and shaly ash mottled red and green, with a coarser band resembling that seen in the beck, the whole having a thickness of about 10 feet. On this rests a little hard grey and dark slaty rock, and then a pink close-textured felsite about 20 feet thick. Above the felsite we enter grey and red evenly-bedded felspathic ashes with some bands indistinguishable, except in their being stratified, from true lava-flows, and with one at least that may be of this nature, perhaps corresponding to the thin vesicular felsite seen in Backside Beck and Wandale in a similar position. In their upper part these ash-beds are traversed by two dykes of mica-trap, one of which reaches $1\frac{1}{2}$ feet in thickness, and both of which have been injected along the bedding-planes. The mica-trap is thus described by Dr. Hatch:—

“(Catalogue No. 1,475). Compact grey rock with dispersed lustrous flakes of mica. Effervesces with acid. Plates of brown mica (biotite) imbedded in a yellowish granular groundmass in which scattered granules of magnetite alone can be distinguished. Pseudomorphs of calcite and chlorite after a well-crystallised mineral (probably olivine) abundantly present. Felspar in microlites in the groundmass, much obscured by calcite-dust.”

After crossing a gap of a few yards, in which nothing is seen, we pass on to splintery Ashgill Shales for a distance of about 20 yards, and reach the base of a waterfall. The section in Watley Gill, though not so clear, corresponds pretty closely to that seen in Backside Beck, and in Wandale.

The waterfall alluded to is formed by a thick dyke of felsite, cutting across the Ashgill Shales in a south-easterly direction, the junction of the shale and igneous rock being well exposed behind the falling water. A couple of yards or so above the brow of the fall a dyke of mica-trap cuts through the felsite, and in a little feeder a few yards to the north, two dykes of the same rock trend about north-north-west. Above the felsite lies dark shale (Ashgill Shales) weathering into columnar fragments, and succeeded at about 160 yards distance from the fall, by the Graptolitic Mudstones. The dykes of mica-trap alluded to have been examined by Dr. Hatch with the following result:—

“(Catalogue No. 1,484.) Dyke in felsite at the top of a waterfall, Watley Gill. Section crowded with blades of brown mica with patches of chlorite resulting from its decomposition. Scattered magnetite and dispersed calcite-dust.”

“(Catalogue No. 1,483.) Dyke in shale in a feeder of Watley Gill. Light-grey rock with large flakes of mica. Long blades and needles of brown mica imbedded in a yellowish-brown groundmass. Small patches of chlorite (pseudomorphous after angite?), isolated granules of magnetite, and large calcareous pseudomorphs (after olivine?). No unaltered felspar visible, but section much obscured by calcite-dust. Calcite also collected in veins.”

The upper part of the Coniston Limestone Series is faulted in again in the valley of Cautley Beck. The best sections occur in Pickering Gill, which enters Cautley Beck from the south, near

its junction with the Rawthey. The hillside here is seamed by channels cut by the rain in soft, dark Ashgill Shales. In Pickering Gill two dykes of mica-trap traverse the shales in a north and south direction, the more westerly occurring in the line of a fault which forms the western boundary of the Limestone Series. No limestone is seen here.

R. R., J. G. G., A. S.

List of Fossils from the Coniston Limestone Series.

- | | |
|---------------------|--------------------|
| 1. West Baugh Fell. | 4. Rawthey Bridge. |
| 2. Murthwaite. | 5. Sally Beck. |
| 3. Backside. | 6. Fairy Gill. |

- Diplograptus pristis*, *His.* 1.*
Favosites aspera, *D'Orb.* 5.*
Heliolites interstinctus, *Wahl.* 5.*
Monticulipora fibrosa, *Goldf.* 5.*
Glyptocrinus basalis, *M'Coy.* 5.*
Myelodactylus (*Herpetocrinus*) sp. 3.†
Calymene brevicapitata, *Portl.* 1.†
Homalonotus bisulcatus, *Salt.* 1.† 5.*
Phacops Brongniarti, *Portl.* 3.†
 „ *conophthalmus*, *Bæck.* 5.*
 „ *obtusicaudatus*, *Salt.* 5.*
Trinucleus seticornis, *His.* 3.† 4.*
 „ *concentricus*, *Eaton.* 1,* 2,* 4.*
Phyllopora Hisingeri, *M'Coy.* 3.†
Chonetes (*Leptæna*) *minima*, *Sow.* 1.†
 „ *sericea*, *Sow.* 1.† 5.*
 „ *transversalis*, *Wahl.* 5.*
Meristella crassa, *Sow.* 3.†
Orthis Actoniæ, *Sow.* 1,* 5.*
 „ *biforata*, *Schloth.* 1.† 3.† 4,* 5.*
 „ *calligramma*, *Dalm.* 4,* 5.*
 „ *crispa*, *M'Coy.* 4.*
 „ *elegantula*, *Dalm.* 1,* 4,* 5.*
 „ *flabellulum*, *Sow.* 4,* 5.*
 „ *hirnantensis*, *M'Coy.* 2,* 6.*
 „ *porcata*, *M'Coy.* 6.*
 „ *protensa*, *Sow.* 1,* 3.†
 „ *sagittifera*, *M'Coy.* 1.*
 „ *testudinaria*, *Dalm.* 1,* 5*, 6.*
 „ *vespertilio*, *Sow.* 1.† 5.*
Strophomena (*depressa*, *Dalm.*), *rhomboidalis*, *Wilck.* 1.† 4*, 5*.
Strophomena expansa, *Sow.* 5.*
 „ *grandis*, *Sow.* 1.† 4*, 5*.
 „ *pecten*, *Linn.* 1.† 4.*
 „ *siluriana*, *Dav.* 1,* 3.†
Pterinea tenuistriata (†), *M'Coy.* 1.†
Tentaculites annulatus, *Schloth.* 1.†

* Collected by Prof. T. McK. Hughes and R. Gibbs.

† On the authority of Prof. R. Harkness.

‡ On the authority of Mr. Marr and Dr. Nicholson (*Quart. Journ. Geol. Soc.*, vol. xlv., p. 700), or identified by Mr. Marr during a recent visit to the locality.

CHAPTER III.—UPPER SILURIAN AND INTRUSIVE IGNEOUS ROCKS.

STOCKDALE SHALES.

This group includes the Pale Slates (or Browgill beds of Mr. Marr and Dr. Nicholson*) above, and the Graptolitic Mudstones (or Skelgill Beds of those authors) below. The Pale Slates correspond with the Tarannon Shales of Wales, and with the Gala Beds as named by Prof. Lapworth in Scotland, while the Graptolitic Mudstones seem to include representatives of both the Upper and Lower Llandovery Beds of Wales, and to correspond with the Birkhill Shales of Scotland. The lower limit of the group is determined principally on palæontological considerations, for there is an abrupt change from the fauna of the Ashgill Shales to that of the Graptolitic Mudstones, without, however, any stratigraphical unconformity.

The Mudstones as a whole are sooty-black, pyritous, and devoid of lamination, except along the bands in which graptolites are abundant; they readily break up into fragments, the faces of which are glazed with ferruginous matter. Their thickness probably amounts to nearly 100 feet, but the sequence is rarely complete owing to the crushing which has taken place along the line of weakness caused by their softness. Upwards they contain bands of pale-green rock, indistinguishable from the Pale Slates, and by the gradual predominance of such bands over the black mudstones pass up into that sub-division, the boundary between the two being fixed solely by the occurrence of certain fossils.

The Pale Slates consist of pale-green and olive-grey mudstones, generally well-jointed and blocky, and in the upper layers usually striped. The bedding is not evident, except in the lower part where the Pale Slates alternate with dark mudstones, and in the upper part where they graduate upwards into the Coniston Flags. The rock seems to be composed largely of a fine felspathic sediment, which is either a volcanic dust or mud derived from the washing of unconsolidated felspathic ash, and in its hardened form often simulates the character and fracture of felsite. No volcanic rocks, however, of this age are known.

The most complete section in this district occurs in Spengill, one of the two principal feeders of Backside Beck, where the group has been divided up into palæontological zones by Mr. Marr and Dr. Nicholson. The following table gives the complete sequence of zones as determined by them from the study of a

* *Quart. Journ. Geol. Soc.*, vol. xliv. p. 659. 1889.

number of sections of the Stockdale Shales of the north-west of England.*

Sub-divisions and Zones of the Stockdale Shales according to Mr. Marr and Dr. Nicholson.

Browgill Beds [or Pale Slates.]	Upper	{	B b 2	}	No fossils.
			B b 1		
	Lower	{	B a 2		Zone of <i>Monograptus crispus</i> .
			B a 1		Zone of <i>M. turriculatus</i> .
Skelgill Beds [or Graptolitic Mudstones.]	Upper	{	A c 5		Zone of <i>Rastrites maximus</i> .
			A c 4		Zone of <i>Acidaspis erinaceus</i> .
			A c 3		Zone of <i>M. spinigerus</i> .
			A c 2		Zone of <i>Ampyx aloniensis</i> .
			A c 1		<i>Monograptus</i> <i>Clingani</i> -Band.
			A b 6		Barren Band.
	Middle	{	A b 5		Zone of <i>Monograptus convolutus</i> .
			A b 4		Zone of <i>Phacops glaber</i> .
			A b 3		Zone of <i>Monograptus argenteus</i> .
			A b 2		Zone of <i>Encrinurus punctatus</i> .
	Lower	{	A b 1		Zone of <i>Monograptus fimbriatus</i> .
			A a 2		Zone of <i>Dimorphograptus confertus</i> .
			A a 1		Zone of <i>Diplograptus acuminatus</i> .

All these zones have been identified in Spengill, excepting part of the Middle and Upper Skelgill Beds, by Mr. Marr and Dr. Nicholson, of whose account the following is an abstract.†

A a 1. They select as the base of the Stockdale Shales a hard limestone-band, 6 inches thick, which is exposed on the right bank of the stream, some little distance above the junction of Spengill with Stockless Gill. This band contains a few crinoids and is correlated by them with the *Atrypa flexuosa*-band which forms the base of the group at Skelgill.

A a 2 consists of black, crushed shales, passing into greyish-black, very fissile shales crowded with Graptolites, and is about 25 feet thick. It contains *Olimacograptus normalis*, Lapw., *Monograptus revolutus*, Kurck., *M. tenuis*, Portl., *M. attenuatus*, Hopk., *M. Sandersoni*, Lapw., *Dimorphograptus confertus*, Nich. (rare), *D. Swanstoni*, Lapw. (abundant), *Diplograptus vesiculosus*, Nich., *D. modestus*, Lapw. (?).

A b 1 resembles A a 2 lithologically, but contains *Monograptus fimbriatus*, Nich., *M. gregarius*, Lapw., *M. attenuatus*, Hopk., *M. triangulatus*, Harkn. (abundant), *Rastrites peregrinus*, Barr., *Diplograptus sinuatus*, Nich., *Olimacograptus normalis*, Lapw. Above these beds is a crush and then blue mudstones, probably the top of the zone of *Phacops glaber*, for they are followed by shales which exhibit a marked olive-brown staining distinctive of the zone of *Monograptus convolutus*. Above these come blue mudstones, and then a considerable fault, which introduces the Upper Skelgill group.

A c 3. In an angle of the right bank which juts out into the stream some little distance below a waterfall, some very black shales, interbedded with lighter bands, appear for about 2 feet below mudstones (A c 4). In the upper part they contain *Monograptus spinigerus*, Nich. (abundant), *M. distans*, Portl., *M. leptotheca*, Lapw., *M. lobiferus*, McCoy, *Rastrites urceolus*, Richter, *Diplograptus Hughesii*, Nich., *Olimacograptus normalis*, Lapw.

* *Op. cit.*, Fig. 13, p. 706.

† *Op. cit.*, pp. 700-705.

- A c 4 consists of 30 feet of blue mudstones, without graptolitic shales, but towards the top with calcareous nodular bands in which occur *Lindstroemia*, sp., *Favosites*, *Phacops elegans*, Böck and Sars., *Cheirurus bimucronatus*, Murch., *Ilænus Bowmanni*, Salt., *Leptaena quinquecostata*, M'Coy. The zone resembles that of *Acidaspis erinaceus*, but has not yielded that fossil at Spengill.
- A c 5 has not been found in any other section in the district. A mass of hard blue mudstones, 24 feet thick, forms a waterfall in Spengill, and a cliff in either bank. The cliff on the right bank forms a cornice, and immediately under this cornice there occur four inches of hard, black, graptolitic shale with *Rastrites maximus*, Carr., and *Monograptus jaculum*, Lapw. (one specimen). Above the mudstones, and at the top of the waterfall, a second band of the same thickness, but lighter in colour, yields numerous examples of *R. maximus*. These two bands with the intervening mudstones constitute the zone of that fossil.
- B a 1, which immediately succeeds, includes 19 feet of pale-green shale, then 4 feet of pale-green and bluish-grey bands with some thin dark seams, then 3 feet of unstriped bluish-grey beds, on which rest 4 inches of dark-grey shales with *Monograptus turriculatus*, Barr. (abundant), and *Rastrites distans*, Lapw. Above it 1 foot 10 inches of pale shale separate it from another greyish-black band, 4 inches thick, with *Monograptus turriculatus*, Barr., *M. Hisingeri*, Barr., *Rastrites distans*, Lapw. Then come 1 foot 6 inches of pale shale, and a third black band, 4 inches thick, with *R. distans*. Lastly there follow 14 feet of pale shale with a concretionary grey bed at top, then green beds with fine shaly bands, many of them stained pink, and some graptolitic, 17 feet, one of the pink bands, 5 inches thick, containing *Monograptus turriculatus*, Barr. (abundant), *M. rectus*?, *Retiolites obesus*, Lapw. The total thickness of this zone amounts to 61 feet 4 inches.
- B a 2 is exposed in the left bank mainly of a shallow valley above the waterfalls in Spengill. It includes 13 feet of green beds with fine shaly bands (at the top of which there may be a fault), and then a thin blue-black band, 2 or 3 inches thick and much baked by a dyke, yielding *Monograptus pandus*, Lapw., *M. griestonensis*, Nicol., *Cyrtograptus*? *spiralis*, Gein. Two or three feet of pale shale separate this band from a sill of felsite, which has been intruded along the bedding, and about 12 feet of pale shale intervene between the felsite and a fine grey gritty shale above, 3 inches thick, with *Cyrtograptus Grayæ*, Lapw. (abundant), *Monograptus pandus*, Lapw., and *Retiolites gemitziensis*, Barr. (one specimen). Above this come 16 feet of pale shales, after which is a gap crossed by a footpath, in which there is room for about 10 feet of rock. The species occurring in this zone all belong to the zone of *Monograptus crispus*, which is found in the immediate vicinity. That fossil, however, has not been detected, either owing to some of the beds having been faulted out, or through the alteration effected by the felsite-sill. About 44 feet of rock are assigned to this zone.
- B b. Above the footpath are 14 feet of green shales, passing up into a great mass of red shales, with interstratified grits, which become greenish-grey towards the passage into the Coniston Flags, the whole having a thickness of about 160 feet.

In Stockless Gill the sequence is incomplete. A mica-trap dyke, 4 feet wide, crosses in the direction N. 26° W., 100 yards up the gill, and is succeeded upwards by hard red shales, which lie in the form of a syncline. About 230 yards up the gill these shales, dipping south and south-east, are traversed by a felsitic sill, which seems to follow the bedding. Above the felsite occur red mudstones, presumably belonging to the Upper Browgill beds (B b), succeeded by grey shales, and fine-grained hard sandstones, dipping northward. Higher up the stream

flows in a rocky channel excavated in dark finely laminated sandstone belonging to the Coniston Flags.

Watley Gill exposes Graptolitic Mudstones dipping north-west, and above them hard grey sandstones and shales (Pale Slates) dipping in various directions. The evidence for the fault here shown is found in Backside Beck (p. 21). Further north along the side of the valley red and purplish slate are mixed with red and green beds. Another fault, which repeats the contemporaneous volcanic series in Backside Beck (p. 24), presumably passes near this spot.

There are no good sections of the Stockdale Shales in Wandale. Between Northwaite and Wandale Farm several small streamlets expose black shales and pale-blue and yellowish shales which seem to belong to the Graptolitic Mudstones and Pale Slates respectively. The latter dip westwards below grey striped sandstone, which contains *Monograptus priodon* in abundance and forms the lower part of the Coniston Flags, the boundary between the two approximately following the margin of the fell. Purple close-grained mudstones belonging to the Pale Slates crop out in Wandale Beck 500 yards south of Adamthwaite, and about 200 yards south of an exposure of Coniston Flags, but from this point eastwards the boundary is conjectural.

But little is seen of the Stockdale Shales in the Cautley Valley. On the shoulder followed by the County Boundary, just south of an intrusive mass of diabase, olive-grey sandy mudstones crop out, and a rain-channel on the southern slope of the hill exposes strata of the character of the Pale Slates.

The River Rawthey cuts twice through the Graptolitic Mudstones near Rawthey Bridge. East of the bridge they are faulted against Coniston Flags; west of the bridge a portion of the Pale Slates intervenes. From one of the two exposures (presumably the western) Prof. Hughes collected *Monograptus exiguus*, Nich., *M. pandus*, Lapw., *Cyrtograptus spiralis*, Gein., *Petalograptus palmeus*, Barr., from black shales interstratified with pale-green shales. These fossils are identified by Mr. Marr and Dr. Nicholson as belonging to the lower part of the Pale Slates (zone of *Monograptus crispus*).*

Five hundred yards east of Rawthey Bridge a dyke of mica-trap, 6 feet wide, crosses the river in a direction N. 35° W., and reappears with a width of 1½ to 2 feet, and a direction N. 42° W. two hundred yards further west. It seems to run close to, but not quite along the fault, which throws the Graptolitic Mudstones of the Rawthey against the Pale Slates of Blue Caster. The dyke is thus described by Dr. Hatch:—

“(Catalogue No. 1,479). Dark-grey compact rock with dispersed lustrous flakes of mica. Veined with calcite. Effervesces with acid. Microscopic appearance similar to that of No. 1,475 (p.), but with larger granules of magnetite and more chlorite. Large calcareous pseudomorphs after olivine (p.)”

On the south side of the Rawthey the Stockdale Shales strike southwards between the Coniston Flags and the Coniston

* *Quart. Journ. Geol. Soc.*, vol. xliv., p. 705. 1888.

Limestone Series, and are faulted in again on the east side of the limestone-series by what is probably an offshoot of the Dent Fault. Towards the northern part of the inlier they have been penetrated by the diabase which forms the hill of Blue Caster. (Catalogue No. 770). The hill offers remarkably few sections; in its northern slopes we find grey rock with bands of black graptolitic shale, and further west, red and green shales, probably belonging to the upper part of the Pale Slates; on its western slopes a single exposure of pale-green mudstone shows that Pale Slates intervene between the diabase and the Coniston Flags somewhere east of the old coach-road; while at its southern end in the head of Fairy Gill we noticed fragments of rock resembling Pale Slates.

Dr. Hatch furnishes the following note on the diabase of Blue Caster, with the remark that the description applies equally well to a dyke in Whinny Gill, mentioned below. The same rock occurs also on the hill north of Cautley Holme Beck:—

“(Catalogue No. 770.) A finely crystalline rock of greyish-green colour. Examined under the microscope it is seen to be much decomposed, the section being made up largely of chlorite in patches which have evidently replaced ophitic masses of augite, as they are penetrated by lath-shaped crystals of felspar. There is also much secondary calcite present, resulting principally from the decomposition of the felspar, which in the larger crystals shows much evidence of alteration. In other parts of the section the lath-shaped crystals form an interlaced *plexus* excluding the other constituents. Iron-ore occurs in scattered granules.”

Taiths Gill crosses the outcrop of the Stockdale Shales for about 250 yards north-eastwards from the Sedbergh road, and exposes purple flags dipping north-west at 40° . They are traversed by two small dykes of felsite, probably offshoots from the great sill described on p. 15, and by a dyke of mica-trap, which appears first on the south side of the stream, and crosses to the north side about 70 yards further on, close to the top of the Ashgill Shales. Taiths Gill exposes the Stockdale Shales again where it crosses the Dent Fault. They are wedged in between Coniston Limestone and Carboniferous Limestone by two faults about 100 yards apart, and near the Carboniferous Rocks are so deeply stained with peroxide of iron, as to have led to a trial for hæmatite having been made a few years ago.

In Birks Field Beck the greater part of the Pale Slates lie below and west of the road, but the Graptolitic Mudstones extend about 60 yards up the gill eastwards before they are succeeded by the Ashgill Shales (p. 15.). In Birks Wood the top of the Pale Slates lies about 30 yards, and that of the Graptolitic Mudstones about 80 yards east of the road, while the Ashgill Shales succeed at a distance of 130 yards from the road. The lower part of the Graptolitic Mudstones crops out at a fork in the line near Mirehouse, and the Pale Slates are seen obscurely in Cross Haw Beck, when they are disordered by two intrusive sheets of felsite (Catalogue Nos. 1,468 and 1,469). A little further east they sweep round, either by a fault or change in the dip, and cross the beck, here known as Whinny Gill, in a direction a little east of north, that is nearly parallel to the Dent Fault. Between them and the Carboniferous Rocks there runs a narrow strip of

Coniston Flags, containing *Monograptus priodon*, Bronn., in great abundance, and *Cyrtograptus Murchisoni*, Carr., on the evidence of which they were identified by Mr. Marr* as belonging to the lowest zone of that sub-division. The flags dip at angles of 60° to 20° towards the Pale Slates and probably therefore are faulted against them, being in fact introduced by much the same combination of faults as that seen in the upper part of Taiths Gill. The Pale Slates where they cross Whinny Gill are traversed by a dyke of diabase (Catalogue No. 1,476) of a similar character to the Blue Caster Rock, and a double dyke of felsite, which attains a considerable thickness in the east bank, but dwindles to a narrow tongue in the channel of the stream (Fig. 4). The felsite-dyke, with the Pale Slates and graptolitic flags, is exposed again in a tributary stream on the east bank, but the best section of the last-named occurs in Whinny Gill at the foot of High Pasture Wood. The following notes on the dykes in Cross Haw Beck and Whinny Gill are furnished by Dr. Hatch:—

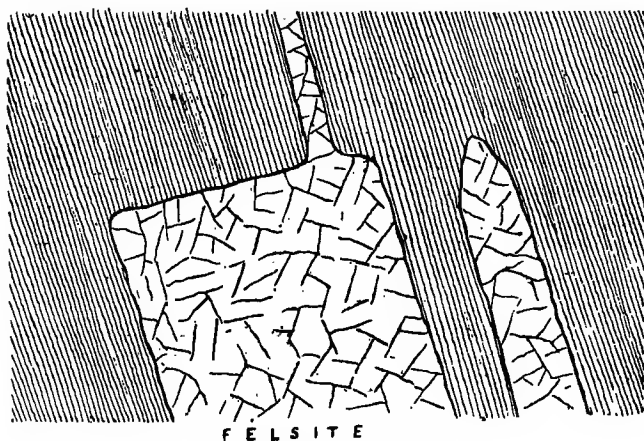
"(Catalogue No. 1,468) The southern sill of felsite in Cross Haw Beck is a cream-coloured minutely crystalline rock, consisting of crystals of both unstriated and striated felspar (orthoclase and plagioclase), imbedded in a crypto- to microcrystalline rather fibrous groundmass of quartz and felspar together with films of muscovite.

"(Catalogue No. 1,469.) The northern sill of felsite in Cross Haw Beck is a salmon-coloured rock of rather more crystalline texture, consisting of a microcrystalline aggregate of quartz and felspar, with a little muscovite. This rock is without porphyritic crystals.

"(Catalogue No. 1,476.) A dyke of diabase crossing Whinny Gill 200 yards west of High Pasture Wood. In this rock lath-shaped felspars penetrate patches of chlorite which have evidently replaced ophitic masses of augite. There is much scattered calcite and some iron-ore in dispersed granules."

FIG. 4.

Plan of a dyke of felsite intrusive in Pale Slates in Whinny Gill. By R. Russell.



Scale about 2 feet = 1 inch.

* During a recent visit to the spot.

Hebblethwaite Gill traverses a small inlier of the Stockdale Shales. The strata, except in minor undulations, dip northwards under the Coniston Flags, while the stream flows south-eastwards, so as to cut obliquely across the strike. The Pale Slates and the passage-beds up into the Flags are exposed, the Graptolitic Mudstones presumably cropping out further south between these and the little patch of Ashgill Shales mentioned on p. 14. On its east side the inlier is bounded by a fault, conspicuous in the banks of the stream from its having served as a channel for the descent of red oxide of iron from the Carboniferous Basement Beds. Professor Hughes obtained *Monograptus turriculatus*, Barr., in Hebblethwaite Gill, and Mr. Marr and Dr. Nicholson found bands with *Monograptus pandus*, Lapw., *Cyrtograptus ? spiralis*, Gein., *Petalograptus palmeus*, Barr., and *Retiolites geinitzianus*, Barr., which indicate that the two graptolitic zones of the Browgill Beds (Pale Slates) are here present.*

CONISTON FLAGS.

This sub-division usually succeeds the Pale Slates without any abrupt change of mineral character. Finely striped beds begin to appear and gradually predominate in an ascending section until the grey bands become altogether subordinate and finally disappear. The Coniston Flags consist of several hundred feet of blocky and flaggy mudstones generally well-jointed and cleaved, with occasional sandy bands. As a rule the rock presents a dark lead-blue tint on an unweathered surface, which passes into various shades of brown after a short exposure to the weather. The ground-tint of the rock is diversified by very fine olive to dark-brown lines of lamination, which are often so close as to put one in mind of the edges of a book. Irregular concretionary nodules of calcareous matter are interspersed throughout the rock, and occasionally develop locally into bands of impure limestone. The predominant argillaceous character of the rock has so favoured the development of cleavage that it is often impossible to obtain an unbroken surface along more than a square inch or so of the bedding-planes. One of the best sections of the lowest beds of the Coniston Flags and the passage down into the Pale Slates occurs in Hebblethwaite Gill, as already mentioned. In Cross Haw Beck they dip southwards near the road, but east of a dyke of mica-trap,† 120 yards east of the road, dip north-westwards and keep this direction close up to the felsite-sill, intrusive in Pale Slates, mentioned on p. 33. There they seem to be terminated by a fault running south-eastwards, of which, however, we obtain a mere glimpse in the stream. The narrow strip which runs northwards along the Dent Fault has been previously noted (p. 33).

* *Quart. Journ. Geol. Soc.*, vol. xlv., p. 705. 1888.

† This dyke is described by Professor Bonney and Mr. Houghton in *Quart. Journ. Geol. Soc.* vol. xxxv. p. 177, and identified as minette.

The mica-trap dyke alluded to lies in the line of a fault, which bounds the Pale Slates of Hebblethwaite on the west, crosses the Rawthey west of Mire House, and then forms the boundary of the Coniston Grits. In the Rawthey the fault appears as a fissure filled with a conglomerate like Carboniferous Basement Beds, and 300 yards north of Crook's Holme it coincides with a dyke of red felsite. It then crosses the Cautley Valley to Benne End, and coincides in Pickering Gill with a dyke of mica-trap.

On both sides of this fault and as far up as the fault near Rawthey Bridge the river runs over Coniston Flags. They dip generally rather to the north of west, in natural succession to the Stockdale Shales, but in some places are much folded, as may be well seen between High Haygarth and Handley's Bridge, within which space they are turned and twisted in every conceivable direction. East of High Cautley Thwaite a felsite-dyke, from 1 to 5 feet wide, crosses the river in a north and south direction, apparently coinciding with the bedding. It lies at the foot of a steep bank formed by an alluvial terrace on both sides of and at a considerable distance above the river. South of the County Boundary the stream exposes some irregular dykes of same rock, and, south-east of Northwaite, a larger dyke of mica-trap, ranging rather west of north.

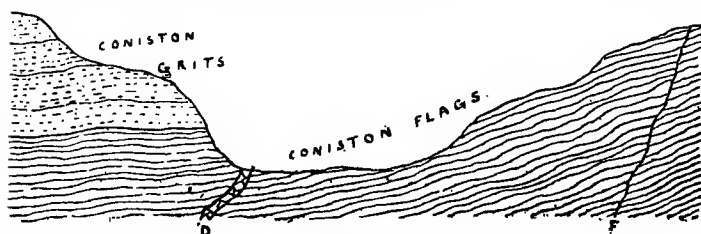
In the north-western slopes of Blue Caster two sills of felsite have been intruded along the bedding-planes of the Coniston Flags. Both are exposed in West Gill near Low Bluecaster Side, and the thicker of the two can be traced on, nearly along the line of the old road, to Far Gill, where it assumes the character of a dyke forking and breaking irregularly through the beds. The flags are hardened, and paler in colour than usual so as to resemble Pale Slates, which, however, crop out 250 yards further up the gill. *Meristella* occurs in the flags at the old road. The larger of the two sills is thus described by Dr. Hatch :—

“(Catalogue No. 1,472), felsite in Near Gill, Blue Caster. This is a cream-coloured rock with small cavities stained with ferric oxide. Under the microscope are seen largish crystals of orthoclase, often showing Carlsbad twinning, and others of striated feldspar. Both feldspars are much kaolinized and are imbedded in a crystalline groundmass made up of larger and smaller granules of quartz and feldspar, together with films of muscovite. The feldspar-crystals are corroded and sometimes have at the periphery a zone of small quartz-blebs. A similar rock occurs at the head of Tait's Gill.”

On the east side of the Rawthey the Coniston Flags form Wandale Hill, which is connected at its north end with the outcrop which extends around the valleys of Backside and Wandale. In Wandale Hill the flags dip at 15° up to 60° westwards and north-westwards, in natural succession to the Stockdale Shales to the east of them; their summit is reached west of Northwaite, where a small area of Coniston Grits is let down in an angle between two faults; but the sequence is incomplete, there probably being a fault near the boundary of the two formations.

FIG. 5.

Section across Backside Beck, north-west of Northwaite, by Professor Hughes

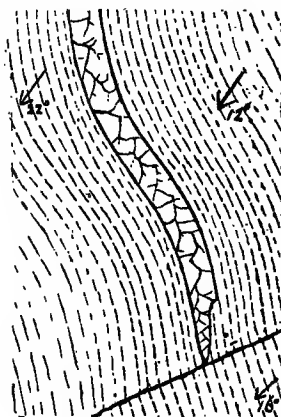


Length of section about 30 yards.

The mica-trap dyke here shown lies in the stream where the base of the Coniston Grit runs along its bank. It is 3 feet wide and extends for about 13 yards, when it abuts against hard bluish-grey sandstone. About 15 yards lower down it reappears in the bed of the stream, and a short distance above the sketch-plan forming Fig. 6 crosses to the east side, its general direction being N. 19° W.

FIG. 6.

Plan of a dyke of mica-trap in Backside Beck, by R. Russell.



Scale about 9 feet = 1 inch.

The lower beds of the Coniston Flags are repeatedly exposed along the eastern slopes of Wandale Hill, where they contain *Monograptus priodon* in abundance, but the best section occurs in the upper part of Spengill, where the passage up from the

Stockdale Shales is fully shown (p. 30). The following fossils have been noted on Wandale Hill :—

Monograptus colonus, Barr.
 " *prionon*, Bronn.
 " *sagittarius*, His.
Cardiola interrupta, Broderip.
Orthoceras subundulatum, Portl.

and from the lower beds of the sub-division near Higher Wards—

Monograptus turriculatus, Barr.

CONISTON GRITS.

Near the top of the Coniston Flags bands of finely-grained micaceous grit are first interstratified with, and afterwards altogether replace, the argillaceous beds which form the principal portion of that sub-division, so that the passage upwards to the Coniston Grits is more or less gradual. The group of strata included in the Coniston Grits may be divided into three portions, viz. :—

1. An upper portion, consisting of tough, micaceous, banded grits alternating with beds of flaggy sandstone, olive mudstone, and an occasional band of fine conglomerate.

2. A middle portion, composed of thinly-bedded and finely-grained grits with subordinate bands of dark-blue mudstone, striped like the Coniston Flags.

3. A lower portion, in the main made up of hard, well-jointed, grey, micaceous grits and sandstones. Thin bands of mudstones showing traces of cleavage, occur at intervals here and there amongst the grits.

The Coniston Grits occupy the greater part of the high ground south of Ravenstonedale. They are faulted down against the Coniston Flags near Backside as already mentioned, and are exposed in various small streams west of the fault. Further north they form the characteristic features of Cautley Crag, Yarlside, and Kensgriff, only portions of which fall within the limits of the map, now under description. They occur also in the foot of the Cautley valley, and are exposed in Lathra Gill, on the east side of the fault. In the Backside valley they are faulted in, as before mentioned; a micaceous grit runs down to the beck just north of the lane from Nanthwaite, and thence follows it northwards, resting on Coniston Flags (Fig. 5, p. 36). Higher up it crosses the beck, but seems to be thrown back by faults, so that its boundary on the whole coincides with the brook.

To the north the main mass of the Grits comes on above the Flags at Grete Fell and Harter Fell, and extending over West Grain and Knott, passes under the Bannisdale Slates on the northern flank of these fells. A series of contortions and rolls in the strata causes many alterations in the dip, but the normal

inclination, which varies from 15° up to 80° , is in a northerly direction. These folds render any calculation of the thickness of the series uncertain, but it is possible that it is not less than 3,000 feet.

Fossils are of rare occurrence. The upper beds have yielded graptolites and orthoceratites, the species of which are not easily determined. The middle beds have furnished the following :—

Monograptus colonus, Barr.

Encrinites.

Orthis.

Rhynchonella nucula, Sow.

The lower beds here and there contain *Cardiola interrupta*, sometimes in considerable abundance.

At the top of Stockless Gill a soft, rotten, red mica-trap dyke forms the steep east side of a ravine. It runs in a N. 33° W. direction and fades to the south-west. On each side of it lies hard grey shale, slightly altered, and stained along the joints with peroxide of iron, much of the shale also being red. Lower down the gill the dyke reappears, but on its west side. Here the beds on either side are slaty and grey, except along the joints, which are coated with peroxide of iron. Generally the strata may be said to consist of micaceous sandy shales with argillaceous bands and gritty sandstones; they probably represent the lower beds of the Coniston Grits. In Dale Gill another dyke, running east and west, seems to coincide with a fault bringing up Coniston Grits against the Bannisdale Slates.

BANNISDALE SLATES.

This is the highest sub-division of the Upper Silurian Rocks existing within the present district. It is composed of alternations of banded dark-grey and olive mudstones, flags, thinly bedded grits, partings of slate, roughly cleaved, and occasional bands of conglomerate. In most instances the argillaceous bands show distinct traces of cleavage. Near the Carboniferous Limestone in Ravenstonedale, the Bannisdale Slates are, in a greater or less degree, stained dull-red and purple. Entering the district from the west at Weasdale, they stretch eastward in a belt, varying in width from three-quarters to one-quarter of a mile, across Dale Gill, Wyegarth Gill and Artlegarth Beck to near Ellergill, where they are overlapped by the lower beds of the Carboniferous Limestone Series.

A north and south fault through Newbiggin intersects the slates at Pinskey Bottom. Another fault, nearly in the same line as the above, throws them down to the east and shifts their base southward.

The following fossils have been obtained from the lower beds of the Bannisdale Slates in Wyegarth Gill :—

Graptolites.
Acidaspis.
Cardiola.
Pterinea.
Orthoceras.

In a fine conglomerate at Greenside Gill the following occurred:—

Chonetes striatella, *Dalm.* (*C. lata*, *V. Buch*).
Orthis elegantula, *Dalm.*
Rhynchonella nucula, *Sow.*
Holopella, *sp.*
Cornulites serpularius, *Schloth.*

R. R., J. G. G., A. S.

CHAPTER IV.—CARBONIFEROUS LIMESTONE SERIES.

For convenience in giving a detailed description of the area occupied by these rocks we will reserve the account of the Millstone Grit for a separate chapter, and place our observations on the Carboniferous Limestone Series under the following headings:—

District 1. The south-western corner of the map, surveyed by R. Russell and A. Strahan.

District 2. Garsdale and Grisdale, surveyed by C. T. Clough, A. Strahan, and G. Barrow.

District 3. (1) Ravenstonedale, surveyed by R. H. Tiddeman, and (2) Mallerstang by J. R. Dakyns and R. H. Tiddeman.

District 4. (1) The valley of the Ure (Wensleydale), surveyed by J. R. Dakyns, C. E. De Rance, and C. T. Clough. (2.) The watershed between Wensleydale and Swaledale, surveyed by T. R. Dakyns and C. E. De Rance.

District 5. Swaledale, surveyed by C. T. Clough.

District 6. Arkendale, surveyed by G. Barrow.

District 7. Surveyed by J. R. Dakyns. (1.) Birkdale and the upper part of the basin of the Swale. (2.) Winton and Kaber Fells.

DISTRICT 1. THE SOUTH-WESTERN CORNER OF THE MAP.

In this part of the area the beds have been highly disturbed and even inverted by the Dent fault, and by the vast compression which has accompanied it. The effect of the steep dip has been to crowd the outcrops into a narrow belt, but unusual as their position is, the limestones can be identified in most of the gills.

The Basement Beds.

This deposit occurs on the west side only of the fault. It rests generally in this neighbourhood on Coniston Flags, but south of Hebblethwaite Hall passes on to Pale Slates and Coniston Limestone, the unconformity between it and the Silurian rocks being most pronounced. The character of the deposit is described by Mr. J. G. Goodchild, lately our coadjutor in the mapping of this country, as follows:—“It consists of a variable thickness of roughly stratified conglomerate, parted by subordinate beds of a finer character. The prevailing tint is a dull Indian-red, which occasionally deepens into chocolate, or becomes variegated with pale-green. The included stones vary from subangular to well-rounded, and range in size from mere grains up to blocks two or more feet in diameter. Most of the materials are arranged with their longer axes parallel to the plane of deposition and they are loosely bound together

by a clayey paste, deeply impregnated with peroxide of iron, which imparts its characteristic tint to the rock as a whole.

"The character of the materials partakes in great measure of that of the rocks lying to the north-west of the district. Sixty to seventy per cent. consist of fragments of the tough grits that occur at intervals throughout the greater part of the Upper Silurian series. Nearly ten per cent. consists of limestone-fragments, not altogether like the limestone that occurs in the older rocks in the immediate neighbourhood, but bearing a close resemblance to fragments which occur in conglomerates of the same age at the foot of Ullswater.

"Associated with these limestone-pebbles are bits of cream-coloured felsite, and representatives of the felspathic hornstones contemporaneous with the Coniston Limestone of this and the areas to the north. Here and there occurs a pebble of jasper, or one of a peculiar micaceous porphyrite like that which occurs in beds of this age in the Pennine area. The remainder of the rock is chiefly composed of fragments of the greenish and olive-coloured mudstones, and fragments of fine conglomerate similar to that occurring in the Coniston Grit, and at higher horizons in the Bannisdale Slates.

"It is particularly noteworthy that fragments of the peculiar striped mudstones characteristic of the Coniston Flags are rare out of all proportion to the area these beds are known to occupy in the surrounding country. It is also worthy of remark that no traces of the Lake District Volcanic Rocks or of the Skiddaw Series can be clearly made out. Quartz-pebbles too are rare.

"Occasionally a few stones are found that exhibit well-marked grooves and striæ. These are, however, easily traceable across the stones into the matrix adjoining, and are rather to be regarded as a form of slickenside than as evidence of the glacial origin of the rock."

The base of the conglomerates appears in Hole Beck Gill on the west side of Longstone Fell, the stream for some distance closely following the boundary, and the steep dip (from 20° to 50°) giving a deceptive appearance of a fault. The pebbles seem to have been distributed over an uneven surface of Coniston Flags, in one place banking themselves against a small prominence formed by a mica-trap dyke in the latter rocks. The same junction comes into view again in the banks of the Clough at Sparram Wood, close to the Dent Fault, where a small inlier of Coniston Flags is exposed as shown on the map. Another fine exposure occurs in Dove Cote Gill, where the conglomerate occupies the position shown in the accompanying figure. The finest section, however, is obtained in Hebblethwaite Gill. The base of the conglomerate crosses the stream at the Hebblethwaite Hall Mills, the Coniston Flags dipping to the north at 45° , and the conglomerate a little south of east at about 20° . The gill runs thence in coarse red conglomerates for

about 500 yards, the dip steadily increasing in steepness eastwards towards the Dent fault. About 100 yards above the point where the stream divides into Nor Gill and Penny Farm Gill the coarse conglomerate gradually gives way to purple and grey sandstones with some fragments, and bands of conglomerate (Lower Limestone Shales), while still further up these sandstones become calcareous and pass into argillaceous and sandy limestones with thin shale-partings and so into massive limestone, thus completing the passage from the coarse conglomerate up into the Great Scar Limestone. Quartz-pebbles, though rare in the lower beds of the conglomerate, become abundant in the upper part of the deposit, viz., the Lower Limestone Shales, which form a passage up into the limestone, and we are reminded here that grains and pebbles of quartz form the principal ingredient of the grits of the Carboniferous Limestone Series and the Millstone Grit.

A narrow strip of the lower beds of the Carboniferous Limestone extends along the west (upcast) side of the Dent fault, from near Hebblethwaite Gill to the Rawthey. As far north as Whinny Gill these strata rest naturally upon the Basement Beds, but from Whinny Gill northward they are bounded by a fault which brings the Silurian rocks against Great Scar Limestone, and which we will distinguish as the West Dent fault. This fault is seen in Whinny Gill, where sandstone and conglomerate forming part of the Lower Limestone Shales abut against red-stained Silurian rocks, the former dipping at a high angle to the south-east.

Whinny Gill, north-west side.

	Ft.
Sandstone - - - - -	-
Shale, seen on the south-east side to - - - - -	8
Sandstone - - - - -	-
Sandstone, conglomeratic at the base - - - - -	8
Sandstone - - - - -	-
Flaggy sandstone extending to the fault - - - - -	-

The dip of the conglomeratic sandstone is E. 30° S. at 65° . Where the flaggy sandstone abuts against the Silurian rocks the strata are nearly on edge.

South of Whinny Gill the fault seems to divide, for while in the upper part of a small brook, which flows westwards from Blake Rigg across High Pasture Wood, Lower Limestone dips E. 5° S. at 60° , and the conglomeratic sandstone rises up from beneath it, in the lower part of the brook red conglomerate is inclined at an angle of 55° in a direction N. 48° W. This would imply either a very sharp anticline or a fault between the outcrop of the Lower Limestone and the West Dent fault.

North of Whinny Gill the Basement Beds seem to die out, for none are seen in the Rawthey, where there is believed to be a natural junction (p. 61), and they are known to be absent in Ravenstonedale (p. 78).

The Great Scar Limestone and Yoredale Rocks along the east side of the Dent Fault.

(1.) The Clough.

In the Clough the Dent fault throws the Great Scar Limestone against Coniston Flags; so far as it is visible it fades to the west, and is therefore "reversed" here, as in the country further south.* The limestone occupies the river-bed for more than 650 yards, with a dip ranging from 90° and 75° near the fault to 45° further away from it, so that the thickness of rock exposed must be considerable, nearly sufficient indeed to include the whole of the sub-division. Excepting three bands of shale from 5 to 7 feet thick, the whole mass is solid limestone. Above it, at Danny Mill, lies sandstone with a band of limestone four feet thick. Eighty and 130 yards further up respectively, the Harddraw Scar and the Simonstone Limestones cross the river with dips ranging from 40° to 90° ; the latter rock is composed as follows:—

The Clough, Garsdale Foot.

							FEET.
Shale	-	-	-	-	-	-	
SIMONSTONE	{	Limestone	-	-	-	-	6
LIMESTONE.	{	Shale	-	-	-	-	6
		Limestone	-	-	-	-	14

A few yards further east the beds suddenly assume their normal horizontal position. A section on the north bank of the river gives the following details:—

Danny Brow Gill.

							FEET.
SIMONSTONE	{	Limestone	-	-	-	-	6
LIMESTONE.	{	Not seen	-	-	-	-	12
		Limestone, not all seen	-	-	-	-	2
Not seen	-	-	-	-	-	-	12
Sandy limestone	-	-	-	-	-	-	2
Sandstone	-	-	-	-	-	-	18
Shale with sandstone	-	-	-	-	-	-	25
	{	Limestone, about	-	-	-	-	6
HARDRAW	{	Shale	-	-	-	-	3
SCAR	{	Limestone	-	-	-	-	1
LIMESTONE.	{	Shale	-	-	-	-	6
		Limestone	-	-	-	-	11

(2.) Dove Cote Gill.

Dove Cote Gill gives a finer view of the fault. For 150 yards from its junction with the Clough it traverses Coniston

* Geology of the Country around Ingleborough (Geol. Survey Memoir), 1890, p. 84.

Flags, but then cuts deeply into the Carboniferous Basement Conglomerate to a point 200 yards above Dove Cote Gill Farm. There the Coniston Flags rise again to the surface, but 80 yards further on terminate abruptly against a wall of limestone, which forms the eastern cheek of the fault. The line of fracture, clearly discernible in either side of the gill, slopes westwards at 52° ; here again, therefore, the fault is "reversed." A larger part of the Great Scar Limestone being cut out here than in the Clough, this rock occupies the ravine for only 100 yards. Soon after passing on to the belt occupied by it, the stream enters an underground passage, and issues, about 65 yards further down, from a cave high up in the limestone wall before alluded to. The subterranean course can be entered at either end, or by an open hole about half-way between. The intensely shattered condition of the rock gives unusual picturesqueness to this ravine.

Above the Great Scar Limestone come the sandstone and thin limestone noticed in the Clough. These are followed by thick shale with sandstone above, and finally by the Hardraw Scar Limestone, which, with the Simonstone and Middle Limestones, is well exposed. Between the two first-named we find as usual principally sandstone with a thin limestone, but in the bed of the stream, about 25 yards above the outcrop of the Simonstone Limestone, we see a seam of coal, 14 inches thick, which does not appear to have been worked. The Middle Limestone is of no great thickness and is split up in the upper part by shale. Above it here, as all through Garsdale, lies a thick fine shale, near the centre of which occurs the persistent band of productal limestone, known locally as the "Horseshoe" or "Cockleshell" from the appearance of the large *Producti* when seen in section.* This band, the Five-Yards Limestone of Alston Moor, is made up as follows:—

Dove Cote Gill.

		FEET.
FIVE-YARDS LIMESTONE.	Impure limestone, weathering red and yellow -	4
	Shale -	2
	Limestone with <i>Syringopora</i> -	1
	Limestone with <i>Productus giganteus</i> abundant -	2
Shale	-	

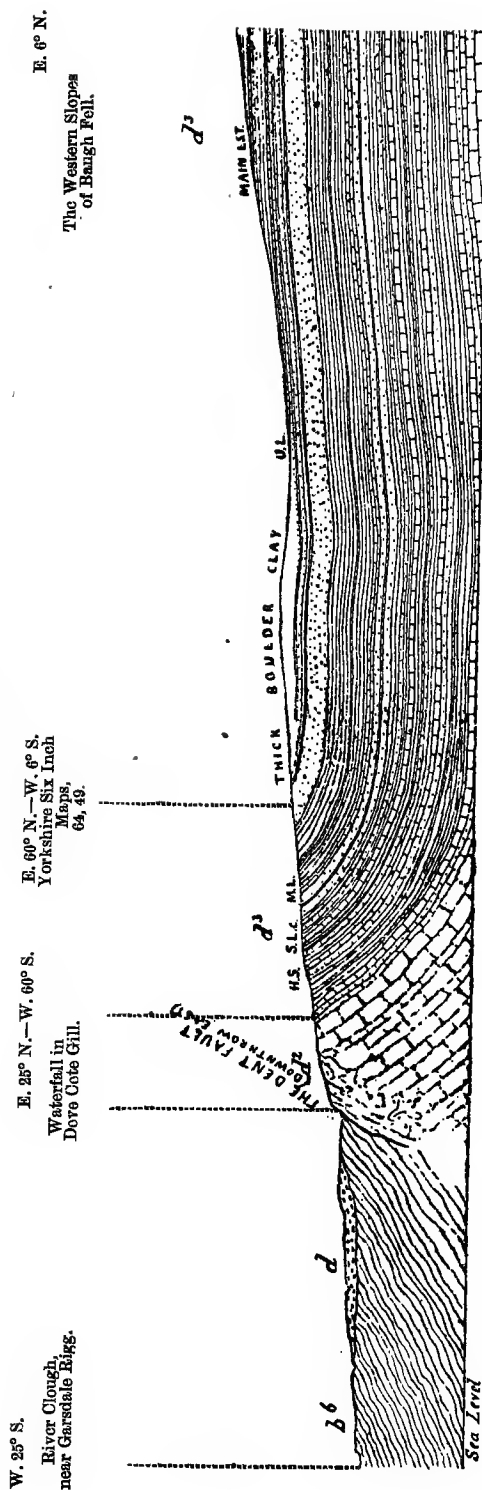
A band, about 2 feet thick, and possibly representing the Three-Yards Limestone crosses the gill 180 yards higher up than the Five-Yards Limestone, but 100 yards further on the section comes to an end. The angle of dip ranges from 90° near the Dent fault. to 3° or 4° at a distance of 650 yards from it.

* This is the Impure Productal Limestone of Phillips.

FIG. 7.

Section across the Dent Fault near Dove Cote Gill.

By A. Strahan.

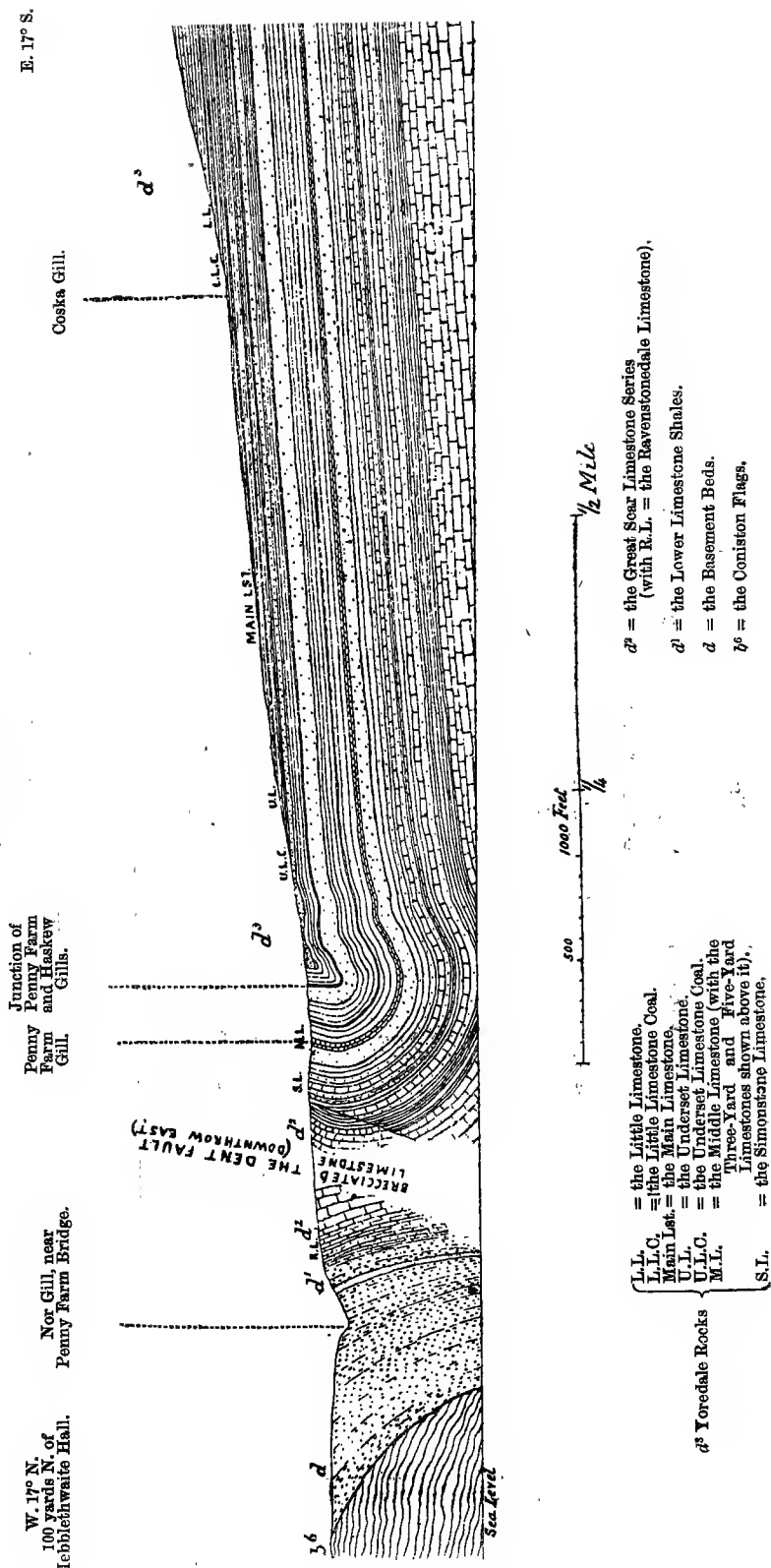


- d³ Yoredale Rocks
- d² = Great Scar Limestone.
d = Basement Beds.
b⁵ = Conistone Flags.
- Main Lst. = Main Limestone.
U.L. = Underset Limestone.
M.L. = Middle Limestone.
S.L. = Simonstone Limestone
with coal (c).
H.S. = Hardraw Scar Limestone.

FIG. 8.

Section across the Dent Fault near Hebblethwaite Hall.

By A. Strahan.



The strata here seen strike nearly east and west, and therefore towards the Dent fault. In consequence of this, and the steep northerly dip, Yoredale are thrown against Silurian rocks immediately north of Dove Cote Gill, while in the Clough the lower part of the Great Scar Limestone was brought into that position. The fault, therefore, acquires a greatly increased displacement in this short distance. A little north of Fell Yeat, however, the strike of the Carboniferous Rocks changes to east of north, and the whole of the beds described above, down to the Great Scar Limestone, reappear. But the fault, instead of running as heretofore between the Silurian (with or without a covering of Carboniferous Basement Beds) and the Lower Carboniferous Rocks, keeps in the middle of the Great Scar Limestone, with the effect of cutting out the middle beds of this sub-division, and throwing its upper part against its lower. The position of the fault in the limestone is marked by a crushed belt of rock, rather than by a sharp line of fracture. Figures 7 and 8 illustrate the different points referred to above.

(3.) Hebblethwaite and Penny Farm Gills.

The section of the Basement Conglomerate in Hebblethwaite Gill has been already noted. The Lower Limestone Shales succeed the conglomerate 120 yards above the point where the gill divides into Nor Gill and Penny Farm Gill. They are about 130 feet thick and pass up by a series of impure limestone of porcelainous texture, interbedded with shales, into the massive rock of the Great Scar Limestone.* The last-named comes on at Penny Farm Caves, with a dip to the east of 60° to 90° , which changes a little further on to an apparent westerly dip of 65° , no doubt owing to an inversion as shown in Fig. 8. We then for about 50 yards pass the belt of crushed rock before alluded to, in which all trace of bedding disappears. In this belt we recognise no definite planes along which displacement has taken place, but the whole mass of rock, after being compressed beyond its "crushing point," seems to have been re-arranged. In few places do we find more fully displayed the crushing and the inversion of the strata which are the noticeable features of the Dent Fault.

A small fault, branching off to the north-east, cuts out the top of the Great Scar and the Hardraw Scar Limestone, and throws in the thin limestones which underlie the Simonstone Limestone, the section being as below:—

Penny Farm Gill.

						FEET.
SIMONSTONE LIMESTONE	-	-	-	-	-	22
Sandstone, thick	-	-	-	-	-	—
Limestone	-	-	-	-	-	3
Shale	-	-	-	-	-	4
Sandstone	-	-	-	-	-	—
Limestone, with 2 feet of shale	-	-	-	-	-	10

* The sequence closely resembles that in North Wales. See *Geology of the Coasts adjoining Rhyll, &c.* (Geol. Survey Memoir).

The Middle Limestone consists of about 8 feet of limestone above, 12 feet of shale in the middle, and 6 feet of limestone below. Above it lies the thick shale, already noted in Dove Cote Gill, the Five-Yards Limestone occurring in its usual position.

Penny Farm Gill.

		FT.	INS.
FIVE-YARDS LIMESTONE.	{ Red-topped limestone in two beds	- 3	0
	{ Shale	-	8
	{ Limestone with <i>Productus giganteus</i>	- 1	9

On the top of this shale occurs a thick sandstone, which forms a noticeable feature in Garsdale (p. 72). Resting upon it, where Haskew Gill joins Penny Farm Gill we find 8 feet of limestone with chert, probably the Three-Yards Limestone. Fifty yards higher up the strata, which so far are all inverted (so as to dip *apparently* westwards), become vertical, and in a few yards abruptly assume the gentle inclination normal to the district, the distance from the fault at which the change takes place being 320 yards.

Continuing our ascent of the gill we next see massive sandstone, overlain by thick shale with a seam of coal. The coal was once extensively worked, and traces of the old shale-heaps, dotted all along this part of the hillside, assist us in tracing the outcrop. The seam is not the same as that worked in Garsdale; the Garsdale coal lies above the Underset Limestone, and has not been found on the west side of Baugh Fell.

The Underset Limestone crosses the gill 160 yards above the coal-crop, the section being as follows:—

Penny Farm Gill.

		FEET.
UNDERSSET LIMESTONE.	{ Black calcareous shale (as seen in Garsdale, p. 72)	- 6
	{ Limestone	- 13
Sandstone	-	- 12
Limestone (about)	-	- 1
Shale	-	- 2-3
Sandstone	-	- 12+

The Main Limestone crosses the gill about 200 yards east of the Underset and reaches a thickness of 16-20 feet, the intervening beds consisting chiefly of shale with two bands of sandstone, and of a thick sandstone which forms the floor of the Main Limestone. Above it lies shale, with a thickness amounting perhaps to about 90 or 100 feet, and containing in the upper part a coal-seam on which a few shafts have been sunk in the Penny Farm Gill. This seam occupies the same geological position as that worked on the north side of Garsdale and identified as the Little Limestone Coal. Above it, in Penny Farm Gill, is found a hard sandstone or quartz-grit, which forms a recognisable horizon along Baugh Fell, though it is less marked and perhaps

absent on the south side of the hill. This is succeeded upwards by a shale containing the Little Limestone, of which the following is a section :—

Coska Gill, the upper part of Penny Farm Gill.

	FEET.
Shale	- - - - -
LITTLE { Chert	- - - - -
LIMESTONE. { Limestone, passing down into	- - - - -
Sandstone	- - - - -
Shale	- - - - -
Sandstone	- - - - -

The remainder of the gill exposes alternations of shale and sandstone for a distance of 250 yards, when a sandy limestone, about 2 feet thick, and containing obscure impression of brachiopods, appears. This we believe to be the equivalent of the Crow Limestone of the north-east corner of this map, though we fail to identify the Ten-Fathom Grit in the underlying mass of shales and sandstones. The base of the Millstone Grit crosses the gill about 300 yards beyond the Crow Limestone, but rock is not seen in place till we reach some flags, about 150 feet above the base of this sub-division.

Between Penny Farm Gill and Taiths Gill a fault running east of, and parallel to the Dent fault, throws in a strip of the upper part of the Great Scar Limestone (Melmerby Scar Limestone). North of Taiths Gill, the Melmerby Scar Limestone occupies the whole space between the two Dent faults, as far as the valley of the Rawthey.

A. S.

(4.) Nor Gill.

For about a third of a mile northwards from its termination in Hebblethwaite Gill, the direction of Nor Gill corresponds nearly with the strike of the beds, the strata being either vertical or inclined to the south of east at angles varying from 25° to 60° , and the stream flowing between straight walls of limestone. In the east bank the lower argillaceous beds (Ravenstonedale Limestone) pass under the Melmerby Scar Limestone, the greater part of which rock, however, is masked by Drift and is indicated only by numerous swallow-holes. The following detailed section of the lower beds of the Carboniferous Series was here taken:—

Nor Gill, through Penny Farm Wood.

Argillaceous and sandy limestone with thin partings of shale - - - - -	Feet.
o 62856.	D

		Ft.
Lower Lime- stone Shales and Base- ment Beds.	Grey calcareous sandstone with green partings and white nodules - -	40
	Red and green shale with hard sandy bands and numerous concretionary white nodules at the top - -	12
	Purple and white mottled sandstone - -	3 to 4
	Red conglomerate - - -	3
	Red sandstone - - -	2 to 4
	Red conglomerate - - -	20
	Conglomeratic grey and purple sandstone with bands of red conglomerate interstratified - -	17
	Red conglomerate of Hebblethwaite Gill, estimated at about - -	900

As we approach the Dent fault, the section becomes more and more complicated, and the limestones, shales, and sandstones are so jumbled up together that it is impossible to identify any of them with certainty.

The fault is not clearly seen, but it is supposed to cross the valley about 80 yards south-west of a sheepfold, where the stream takes a more easterly course. On the west side of this place we see shale with thin sandstone, similar in character to the argillaceous lower limestones already mentioned; and on the east side, limestone, apparently brecciated, and interstratified with shale, and probably forming part of the Melmerby Scar Limestone. This limestone continues as far as a bend in the gill about 50 yards north-east of the sheepfold. A fault parallel to, and forming part of the Dent fault is supposed to cross here, a belt, about 80 yards in breadth, of Melmerby Scar Limestone lying between the two (p. 49).

About 200 yards south-west of the supposed place of the fault the limestone on the north side of brook is succeeded by yellow sandy limestone, and this, by broken and jointed sandstone containing a band of shale. The limestone strikes S. 8° E. and dips apparently westwards at 57°, but at a bend in the stream and on its north side vertical limestone strikes W. 13° S., or almost at right angles to that above-mentioned, there being most probably an east and west fault here. North of this point the section is obscure for a distance of about 50 yards, but sandstone, shale, and limestone are seen in places dipping in various directions and at varying angles. These continue until shattered limestone is brought in apparently by a fault which crosses the valley in an E. 5° N. direction and fades to the south. This shattered rock extends northwards for about 44 yards farther, when what seems to be a fault hading to the south at 60° and running W. 17° N., brings in on its north side solid blue limestone, differing most distinctly from the weathered and faulted rock on its south side.

Limestone continues along the north-west side of the stream as far as a path across the valley. Here it contains a band of flaggy sandstone. On the south-east side the sandstone is

shifted its own breadth to the north-east along a joint which must run along the bottom of the gill. The limestone occupies a space of 49 feet on the north-west side and dips E. 41° N. at 78° . But there is no corresponding limestone on the south-east side, though the fault which shifts the sandstone-band is not sufficient in itself to throw out the limestone altogether. The gill now turns sharply to the south-east. At the bend dark shales are brought in very curiously. They have the appearance of being contorted, and of having been completely squeezed out by the sandstone, for the limestone and sandstone lie close together higher up the stream. The Dent fault probably runs through at this bend and accounts for the absence of the limestone mentioned above on the south-east side of the brook.

The gill here falls nearly into the line of strike of the rocks, the direction of which is N. 35° W., and the dip south-west. The following strata are exposed:—

Nor Gill, 10 yards east of the East Dent Fault.

				FEET.
Limestone	-	-	-	10
Dark shale	-	-	-	3
Limestone	-	-	-	5
Dark shale	-	-	-	2
Sandstone	-	-	-	5

} d.

About 20 yards east from this sharp turn in the stream a fault, throwing down to the south-east, crosses in a direction S. 16° W., and brings the dark shale between the two limestones down to the south side of the channel. Eighteen feet farther east a second fault crosses in a direction S. 22° W. and throws the shale up again, the water now running in a course cut out of the shale between the sandstone and the limestone.

The gill again turns towards the north-east, and at the bend intersects a band of limestone 3 feet thick. Here there is a complete change in the strike of the beds. This limestone crosses in a direction N. 16° E., with an apparent dip W. 16° N. at 65° . The sandstone on its east side shows smoothed and striated joints, and although the actual break is not seen there must be a fault running through here in the direction shown on the map. The limestone and the rocks in its immediate vicinity are probably inverted, so that the real downward succession will be as follows, although the sandstone at the bottom of the section seems to be the highest rock:—

Nor Gill, 20 yards east of the East Dent Fault.

							Ft.	Ins.
Sandstone	-	-	-	-	-	-		
Dark shale	-	-	-	-	-	-	1	0
Sandstone, an irregular band	-	-	-	-	-	-	1	1
Dark shale	-	-	-	-	-	-	5	6
Dark shale with bands of limestone	-	-	-	-	-	-	1	6
Limestone	-	-	-	-	-	-	3	0
Sandstone	-	-	-	-	-	-		

The sandstone at the top of the foregoing section continues north-east above a little waterfall. It is shattered and shows slickenside. Above it come dark shales and then a limestone 7 feet 6 inches thick, vertical and striking S. 37° E. with about 2 feet of soft material on its east side resembling "fault-stuff." Dark shales come next, and these are succeeded by sandstone more or less flaggy, dipping E. 44° N. at 80°. Then follow alternations of sandstone and shale containing two bands of earthy limestone 2 feet and 1 foot 4 inches thick respectively. Here the dip is E. 25° N. at 75°. Above these strata comes the Middle Limestone consisting of an upper and lower bed with shale between them. This is overlain by dark shale with nodules of ironstone, containing a limestone 2 feet thick, and this by dark shale with sandstone and flaggy bands. The dip is here E. 40° N. at 60°.

The Five-Yards Limestone comes next in succession and gives the following measurements:—

Nor Gill, 145 yards east of the east Dent Fault.

		Ft. Ins.	
Dark shale with nodules of ironstone	- - - -	-	-
FIVE-YARDS	{ Limestone with <i>Productus giganteus</i> at the base	-	-
LIMESTONE.	{ Shale	4	6
	{ Limestone	0	9
		2	3
Hard flaggy sandstone	- - - -	-	-

At this place a small fault throws down the dark shale and sandstone against the flags under the limestone.

East of the Five-Yards Limestone is dark shale and then sandstone. The strike now changes to N. 14° E., and the sandstone follows the east side of the brook, which here runs for a short distance in that direction. Dark shales with sandy bands and ironstone-nodules continue up to a small waterfall. Here a fault sloping to the east and ranging S. 23° W., brings in a massive sandstone which extends eastwards to another small waterfall, where another fault, which hades to the west at 60°, crosses in a direction S. 10° W. Above this the dip becomes less, and at a bend in the stream, above a waterfall, hard sandstone with soft bands dips S. 57° E. at 22°. At the next bend a band of limestone, about 4 feet thick, is poorly exposed.

Eastwards we pass up over a series of dark shales and sandstones, the dip, 120 yards east of the limestone, decreasing to 15° in a direction E. 17° S. The Underset Limestone occurs at a sharp bend in the stream, about 230 yards farther to the north-east. It is followed by black and yellow shales, and these by sandstone with bands of shale, which begin to run down into the gill where a small brook enters from the north side, and reach the bottom at a waterfall. Here the dip is S. 37° E. at 7°.

The Main Limestone comes on east of this waterfall, and is succeeded by dark shale interbedded above with bands of sandstone, lying nearly flat. Above those lies hard sandstone which passes up into coarse grit, the Coal-Sill. As we ascend, the strata given below follow in regular order, until the brook is lost in the peat which covers the side of West Baugh Fell.

Nor Gill on West Baugh Fell.

Dark shale.
Dark sandy chert (the CROW LIMESTONE).
Shales.
Sandstone, flaggy.
Shales with bands of sandstone.
Dark shale.
Cherty sandstone (the LITTLE LIMESTONE).
Dark shale with bands of sandstone.
Grit - }
Flaggy sandstone - } Coal-Sill.
Dark shale and sandy shale.
THE MAIN LIMESTONE.

(5.) Whinny Gill.

The section in this gill in the vicinity of the West Dent fault has 'already been described (p. 42). East of the fault thinly-bedded limestone with thin bands of shale comes on above the conglomeratic beds. This limestone is also on end, but rolls slightly in the direction of the dip. Sandstone, with a calcareous band in the centre, dipping E. 28° S. at 70° , runs thence along the north-west side, and limestone along the south-east side of the gill, the stream cutting into the limestone with shale-bands (Ravenstonedale Limestone) for a short distance. Above its junction with Gutter Scales thinly-bedded limestone is seen in the channel of Whinny Gill, followed by massive limestone, the strike of which seems to be E. 7° N. The next exposure of limestone lies north of the road to Marsh Yeat, where it dips E. 38° S. at 40° , and is followed by sandy calcareous beds dipping W. 30° N. at 70° .

The stream here divides. Following the northern branch we next see a limestone resembling the Melmerby Scar Limestone. We have not ventured, however, to correlate it as such, but have included all the beds here exposed in the Ravenstonedale Limestone. About 280 yards above the division of the stream limestone dips E. 38° S. at 70° , and here the water disappears under the surface. A small mossy flat now borders the stream, and we see no solid rock until we come to a hard sandstone striking across the brook in a direction N. 38° E., but there are many fragments of the lower limestones in the soil. Still higher up we again cross the Dent Fault, and, at the road leading to Birks, find an exposure of Coniston Limestone Shales.

Turning now to the central branch of the stream we see vertical limestone striking N. 42° E. East of a small valley, about

half-way up this branch, and on its north side, we observe alternations of limestone and shale, dipping E. 44° N. at 70° , all forming part of the Ravenstonedale Limestone.

A change in the direction of the dip takes place almost immediately, for some thinly-bedded, grey, sandy limestone next seen is inclined at an angle of 50° in a direction N. 6° E., and is followed by calcareous sandstone and earthy limestone, which dips N. 16° W. at 53° . At this place some whitish clayey shale, with a south-westerly strike, lies in a vertical position, possibly in consequence of a fault. Shale occurs higher up on the north side of the stream, and is succeeded by sandstone and sandy shale which dip W. of N.

A small trench on the eastern side of Whinny Gill exposes a limestone, sandstone with shale partings, apparently immediately below the limestone, and shale below the sandstone again. Farther eastwards soft black shale dips to the N.W. at 65° , while at the top of the stream sandstone dips W. 25° N. at 70° , with an intermediate band of limestone which forms a little grassy knoll on the north side of this little valley. All the strata here seen are probably inverted.

(6.) Gutter Scales.

The section here exposed more nearly resembles those in Nor Gill or Taiths Gill. East of the junction with Whinny Gill the lower beds of the limestone series, consisting of sandy shale, shale and impure earthy limestone, dip E. 30° S. at 54° . Above them, at a limekiln and as far eastwards as a sharp southerly bend in the stream, we find a limestone which might be included in the Melmerby Scar Limestone, but at the next turn in the brook there is a cliff composed of bands of blue and grey limestone, the grey limestone not differing much in appearance from those in the lower series. Here the strata are vertical and strike S. 30° W.

The brook now follows a ravine cut out in weathered limestone, dipping N. 34° W., and containing a thin band of soft dark shale, best shown on the north side. Similar rocks continue until a band of blue limestone strikes across the ravine in a southerly direction. A little farther to the east a band of soft dark shale, dipping W. 30° N. at 55° , is succeeded by thin limestone with shale-bands, probably the Five-Yards Limestone.

Gutter Scales, 10 yards east of the east Dent Fault.

				Ft.	Ins.
THE FIVE-YARDS LIMESTONE (P).	Limestone with red top	-	-	3	6
	Shale	-	-	4	0
	Limestone	-	-	2	0

East of this outcrop and on the south side of the ravine a band of hard sandstone is exposed, but farther east again, the cliff is

entirely composed of dark shale. Close to the hard sandstone the dark shale is vertical, but near the top of the cliff apparently dips to the east.

Alternations of sandstone and shale continue up to and east of a limestone-band 5 feet in thickness, and strike S. 35° W., but turn rather more westwards at a dark shale which follows the thickest bed of sandstone. A limestone seen here in the brook, if *in situ*, strikes against the sandstone and indicates a fault, possibly one of those seen in Nor Gill. Dark shale now occurs on both sides of the ravine until we come to a flaggy sandstone, striking S. 42° W. across the stream. Here the gill turns to the northwards and following the strike flows for about 70 yards in a gorge cut down between some of the sandstone-bands. It then again turns eastward and passing across the strike of the strata shows alternations of sandstones and shales, in a vertical position and striking S. 30° E., as far as a waterfall. At a sharp bend above the waterfall, a band of limestone 7 feet thick, and also vertical, trends in a direction S. 31° W. A band of yellowish white sandstone and soft finely grained sandstone lies next below the limestone, and itself rests upon a hard, fine-grained, gannister-like rock, which much resembles a sandstone seen in a small brook south of Gutter Scales, where it forms a well-marked ridge. This ridge continues southward, enclosing a small hollow between itself and the line of some old coal-workings. But if the limestone in Gutter Scales and the limestone over the thick sandstone in Nor Gill be the same bed, it must be thrown down to the west by the continuation of one of the faults seen in Nor Gill.

From the limestone-band in Gutter Scales, dark shale with bands of ironstone continue eastwards to the road to Marsh Yeat. Above the road dark shale and sandstone, ranging nearly in the same direction as the limestone, are also vertical, but at a bend in the gill turn over and have an apparent dip W. 20° N. at 53°. They are overlain by a sandstone, apparently unconformably, the appearance being in reality produced by a shift due to lateral pressure. A small fault throws the strata 1 foot down to the west here, and a larger fault throws up the sandstone-bed on the east above the surface of the brook. The section at the fault being as follows :—

Gutter Scales, about 30 yards east of the road to Marsh Yeat.

	Ft. Ins.	
Dark shale - - - - -	-	-
Sandstone - - - - -	6	0
Sandy shale with thin bands of sandstone - - - - -	2	0
Dark shale - - - - -	1	3
Flaggy sandstone - - - - -	5	6

Sandstone continues along the south side of the brook for a short distance and is followed by dark shales and these by dark earthy sandstone which dips E. 25° S. at 55° . This is likewise overlain by dark shale. In the north bank a band of hard sandstone dips E. 18° S. at 62° .

At a sharp bend in the stream dark shale dips at a high angle, but on the opposite side lies flat, or nearly so. East of this, a small cliff on the south side of the brook displays the shale well. Near its bottom are sandy beds which form dark flags, and at its top there is sandstone-rubble. Higher up the stream dark sandy shale lies under flaggy sandstone. Farther north the dip of the sandstone is E. 24° N. at 50° .

(7.) Taiths Gill and Blue Caster.

The West Dent Fault crosses Taiths Gill at a point where the brook turns sharply to the north-west. The section is not clear enough to show the actual fault, but to the west of this bend Pale Slates, in part stained red (p. 32), are exposed. Working eastwards from the fault, we see first a hard sandstone on the north side of the ravine. This rock dips W. 40° S. at 70° , and is succeeded by a limestone, also much jointed and containing irregular layers of black carbonaceous matter. It occupies both sides of the gill, but there seems to be a break running across in an E. 22° N. direction, for the dips on the two sides of the valley do not correspond. On the north side of the gorge hereabouts there is an enormous mass of limestone-fragments cemented together in a matrix of calcareous clay resembling such material as occurs in faults.

The river now comes through a narrow gorge in the limestone on the west side of the east Dent Fault. Here a band of flaggy sandstone strikes across in a direction S. 30° W., dipping at 60° . The following is the apparent succession of the strata:—

						Ft.	Ins.
Flaggy sandstone about	-	-	-	-	-	10	0
Sandy limestone	-	-	-	-	-	1	8
Limestone	-	-	-	-	-		
Thinly-bedded limestone	-	-	-	-	-		
Limestone	-	-	-	-	-		

A small fault shifts the thinly-bedded limestone on the south side of the gorge in the manner shown in the accompanying plan:—

Fig. 9.

Plan of a small fault in the Carboniferous Limestone in Taiths Gill.

By R. Russell.



Scale, 3 feet = 1 inch.

a Massive limestone.

b, c, d Thinly bedded limestone.

The fault trends north-east and shifts the beds marked (*b, c, d,*) to the east about 3 feet; but on reaching the bed (*b*) on its south side, runs along it for about 4 feet before it continues its eastward course. On the north side of the gorge the slips in connection with this small fault are much more complicated. A prolongation of this fault eastwards would carry it into the main fault.

The east Dent Fault crosses the valley in a N. 22° E. direction and brings in the strata above the Great Scar Limestone. The hade varies considerably. On the north side, near the top of the bank, it is nearly vertical, but on the south side it slopes at 45° to the E. 22° S., so that a flaggy sandstone on the downthrow side is brought down to the limestone on the upthrow side of the fault.

The water falls over a dark earthy limestone which ranges N. 33° E., and has an *apparent* dip westward of 62°, the rocks being in reality inverted, so that as we proceed eastwards we pass over beds higher and higher in the series, although we seem to be doing exactly the reverse. This inversion of the strata, with the sharp folding presently to be described, is illustrated in the accompanying figure.

The limestone extends almost to a road which here crosses Taiths Gill. Flaggy sandstone containing a band of earthy limestone next comes in, and is succeeded by another limestone which extends eastwards from the road for a distance of about 8 yards. It is not easy to identify these limestones, but it is probable that the first-mentioned is the Hardraw Scar and the last-named the Simonstone Limestone. Dark shales

Fig. 10.

Section across the Dent Fault near Taitbs Gill.

By A. Strahan.

E. 50° S.—W. 31° N.

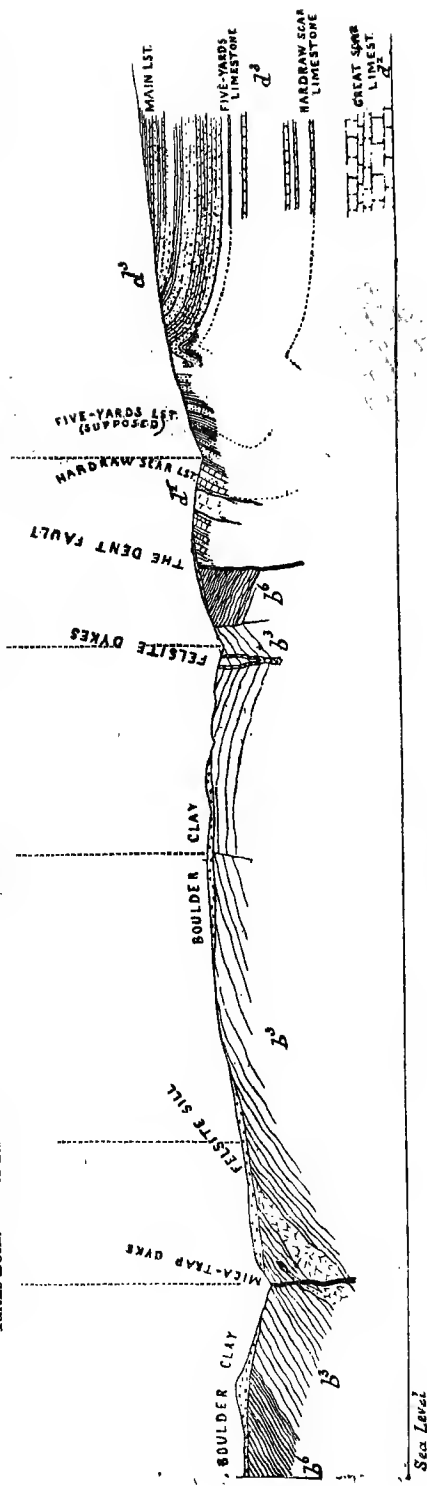
Taitbs Beck.
Lane
250 yards S.W.
of Taitbs.

E. 31° S.

West Baugh Fell.

Taitbs Beck.

Taitbs Beck.



d^3 Yoredale Rocks.

d^2 Great Scar Limestone.

d^1 Stockdale Shales (p. 32).

d^4 Conistone Limestone Series (pp. 15, 16).

and sandstones occur on the east of these outcrops. Where the stream turns to the north-east above a waterfall, it exposes bands of dark shale and hard sandstone, its course here nearly following the strike of these beds which dip W. 24° N. at 58° . At the next bend in the stream the hard sandstone, occurs in nodular masses and thin bands with dark shale-partings. It is followed by dark shale with bands of sandstone, the shale containing a bed of ironstone with casts of *Spirifer*. The limestone, which is 8 feet thick, runs N. 37° E. across the valley, and dips at 75° . This bed we have taken to be the Five-Yards Limestone, an identification which, however, is uncertain, for several of the distinct characteristics of that band are wanting, nor was any trace of the Middle Limestone found in the strata on its west side, nor, indeed, anywhere in the Taiths Gill section.

To the east of this band there follows a great thickness of dark shale with ironstone-nodules, which is succeeded by sandstone, apparently having next to it another bed of limestone 4 feet thick. The sandstone dips W. 30° N. at 80° , and the limestone trends much in the same direction, but at the top of the bank becomes vertical. Dark shales, alternating with flaggy sandstone follow next, in a vertical position and striking N. 30° E. They occupy a space of about 50 yards, but above this the section is not clear; the rocks seem to consist mainly of shales with a band of sandstone.

West of the junction of a small brook on the north with Taiths Gill there is a very sharp anticline. The channel of the stream is cut through sandstone containing two thin bands of limestone dipping on the west side W. 32° N. at 62° . Within a space of 86 feet the beds roll over, and the dip at the mouth of the small brook on the east side is E. 27° S. at 56° . The sequence of strata runs as follows:—

Taiths Gill, 450 yards east of the east Dent Fault.

						Ft.	Ins.
Sandstone	-	-	-	-	-		
Sandy shale	-	-	-	-	-		
Shale	-	-	-	-	-		
Limestone, encrinital	-	-	-	-	-	7	0
Sandstone	-	-	-	-	-	4	0
Shale	-	-	-	-	-	6	0
Limestone	-	-	-	-	-	2	0
Sandstone	-	-	-	-	-		

In the space between the anticline and the vertical strata on the west, the beds overlying those in the above section are bent on both sides of the ravine into a very sharp syncline.

The measures east of the anticline are apparently the dark shales and sandstones which occur on the west, repeated by a fault, although the sections are not precisely the same. High up on the side of the ravine a band of sandstone dips towards the east, at angles varying from 60° to 90° . It is overlain by shale, sandy shale, and flaggy sandstone.

From the place marked "Cinder Oven" on the 6-inch map the dip is less steep, and where shaly sandstone runs down into the channel of the brook, it falls to 34° towards S. 40° E., but along the south bank the strata turn up more quickly. In due course all these strata run down to the brook, with a dip of 15° towards E. 28° S. Sandstone-blocks and fallen *débris* now obscure the section for a short distance, but below and up to an old shed, sandstone occurs in the bottom of the gill. Still further eastwards flaggy sandstone rests on dark shale. The beds now, though gently undulating, become nearly horizontal.

The Underset Limestone might have been expected to crop out between the Cinder Oven and the Shed. No trace of it, however, was found. But the sandstone and dark shale east of the anticline much resemble those which lie below that limestone in the Rawthey.

Dark shales and flaggy sandstones extend as far east as a sheepfold. Beds higher in the series come in gradually until the position of the Main Limestone is indicated by a large number of limestone-blocks. This limestone is overlain by dark shale, flaggy and coarse sandstone, shales, and a thin band of limestone, the equivalent of the Little Limestone. The last-named is followed by dark shale containing three principal bands of sandstone, the uppermost of which is the thickest. Near where the stream first begins to cut out a distinct channel for itself, the representative of the Crow Limestone, a band of black chert, 2 inches thick, is visible. The succession above the Main Limestone is exactly similar to that already referred to in the description of Nor Gill (p. 53).

Continuing northwards from Taiths Gill, we find little difficulty in tracing on the Deut faults, by means of sections of Silurian Rocks north of Peter's Moss, and of Great Scar Limestone, the largest exposure of the latter occurring south of the road from Bluecaster Gate. North of Raven Thorn Gill several swallow-holes mark the east side of this fault, where also rocks belonging to the Yoredale Series are exposed.

Almost due east of the head of Bluecaster Gill limestone, apparently vertical, is seen in a swallow-hole. About 100 yards farther north, in another large swallow-hole, limestone dips W. 28° N. at 70° . In a third swallow-hole, about 40 yards farther north, the following strata, dipping W. 23° N. at 70° , were measured:—

Swallow-hole near Bluecaster Gill Head.

					Ft.	Ins.
Limestone	-	-	-	-	-	-
Limestone in thin beds	-	-	-	-	3	0
Shale	-	-	-	-	0	4
Limestone	} forming one bed					
Dark calcareous sandstone					1	0
Shale, about	-	-	-	-	6	0
Limestone ?	-	-	-	-	2	0
Shale, about	-	-	-	-	5	0
Hard sandstone	-	-	-	-	-	-

Similar beds are seen in the next swallow northward where the dip is W. 20° N. at 65° . The swallow-hole, which is marked "Cavern" on the 6-inch map, shows, on the west side, sandstone containing a band of dark shale with the same dip as that last given. Limestone occurs in the middle, occupying about 6 yards of the section exposed, while dark shale with a soft clay-band lies on the east side. At the surface these shales seem to turn over and dip to the east. They are, however, probably inverted.

(8.) The Rawthey.

There are excellent sections exposed in the River Rawthey from its rise on Baugh Fell throughout the whole of its course. East of the West Dent fault, limestone seems on the south side of the valley to rest naturally upon the Pale Slates, but, directly north of Hall Intack, is thrown down by a fault from the hill-side to the level of the river, which has cut a narrow gorge through it. The stream runs for about 80 or 90 yards between cliffs of massive limestone, dipping N. 58° W. at 70° . Dark shales with thin bands of limestone occur next, dipping E. 27° S. at from 80° to 82° . Further east, a massive limestone followed by shales, sandstones, and limestone is well exposed in the south side of the gorge. Another massive limestone, also followed by shales, sandy limestones, and sandstones, succeeds, and the Hardraw Scar Limestone coming next continues as far as a wooden bridge, where the dip is E. 29° S. at 78° . The following section gives the complete sequence from the bridge to the fault:—

The Rawthey, from a wooden bridge to the West Dent Fault.

	Ft.		Ins.	
HARDRAW SCAR LIMESTONE	-	-	-	
Sandstone	-	-	-	
Fault down east.				
Dark shale	-	-	-	
Sandstone	-	-	-	3 0
Dark shale	-	-	-	27 6
Limestone	-	-	-	5 6
Dark shale	-	-	-	4 0
Limestone	-	-	-	4 2
Hard sandstone	-	-	-	3 6
Hard dark shale	-	-	-	2 6
Hard sandstone	-	-	-	3 6
Sandy limestone	-	-	-	5 0
Shale	-	-	-	0 3
Hard grey sandstone	-	-	-	3 0
Hard, dark, sandy shale	-	-	-	3 8
Shale with encrinurites	-	-	-	1 6
Limestone	-	-	-	3 4
Dark shale and nodular bands	-	-	-	17 6
Limestone, about	-	-	-	50 0
Sandstone	-	-	-	3 0

	Ft.	In.
Shale - - - - -	6	0
Hard sandstone - - - - -	5	0
Dark shale with sandy bands - - - - -	7	3
Limestone, cherty on the top - - - - -	5	0
Chert - - - - -	0	5
Dark shale - - - - -	1	6
Sandstone - - - - -	1	1
Dark shale - - - - -	6 ins. to	0
Sandstone - - - - -	0	6
Dark shale - - - - -	6 ins. to	0
Flaggy sandstone - - - - -	1	0
Dark shale - - - - -	1	3
Limestone, about - - - - -	72	0
Grey shale with bands and nodules of limestone - - - - -	12	0
Grey limestone, thinly-bedded - - - - -	4	8
Shale - - - - -	8	3
Black limestone, thinly-bedded - - - - -	2	6
Hard dark calcareous shale - - - - -	1	8
GREAT SCAR LIMESTONE; the lower beds abutting against the Dent Fault - - - - -		

The dark shale rises up on the west side against the sandstone as if it were unconformably overlain by it. The sandstone dips E. 29° S. at 78° and passes under the Hardraw Scar Limestone at the wooden bridge, where the inclination is 72° . East of the bridge the ravine widens and the section becomes obscure. On the path along the side of the valley finely grained sandstone dips at a high angle, apparently in the same direction as the limestone.

In a small brook between the wooden bridge and Hall Intack Bridge the Simonstone Limestone crops out. In a cliff on the west bank, above the outcrop of the limestone, the following section was measured:—

The Rawthey Valley; in a brook west of Hall Intack Bridge.

	Ft.	Ins.
Shale - - - - -	-	-
Sandstone - - - - -	3	6
Shale with bands of sandstone - - - - -	7	0
Sandstone - - - - -	4	0
Dark shale with sandy bands - - - - -	9	0
Hard fine-grained sandstone - - - - -	6	6
Dark shale, about - - - - -	20	0
Simonstone Limestone - - - - -	-	-

The dip of the shale is W. 4° N. at 28° , or in the opposite direction to that at the wooden bridge.

The Simonstone Limestone, with a sandstone below it dipping W. 14° S. at 9° , occurs on the south side of the river, and runs thence by a limekiln through Rowantree Gill. East of Hall Intack Bridge it passes down into sandy limestone and this into a hard quartzose sandstone, on which the water runs. At first the beds roll slightly but then acquire a general westerly dip of 14° or 15° . From below the sandstone a shale

next comes up into the section, then a band of impure limestone containing fossils, the section being as follows:—

The Rawthey, 25 yards east of Hall Intack Bridge.

	Ft.	Ins.
SIMONSTONE LIMESTONE - - - - -	-	-
Hard quartzose sandstone - - - - -	-	-
Shale - - - - -	-	-
Impure limestone with fossils - - - - -	2	0
Shale - - - - -	2	0
Limestone - - - - -	0	6
Sandstone - - - - -	1	10
Sandy shale - - - - -	2	6
Sandstone - - - - -	-	-

Eastwards the shale runs along a cliff on the south side of the river, while the impure limestone comes down into the bed of the stream east of the fence at Intack House. At this fence a higher band of shale, with sandstone below it, runs along the middle of the cliff. Proceeding eastward the sandy limestone rises up again on the south side of the river with a dip to W. 24° N. at 10° , but the strata now begin to rise more rapidly eastwards and the Harddraw Scar Limestone where it comes up in the river is inclined W. 6° N. at 16° . Here the river bends southward, and cuts through the upper beds of that limestone into a band of shale. A cliff on the south-west side gives the following section of the strata immediately above:—

The Rawthey, 300 yards below Needlehouse Gill.

	Ft.	Ins.
Flaggy sandstone - - - - -	-	-
Shale - - - - -	-	-
Flaggy sandstone - - - - -	-	-
Limestone - - - - -	-	-
Shale - - - - -	-	-
Sandstone - - - - -	-	-
Shale - - - - -	-	-
Flaggy sandstone - - - - -	-	-
Dark shale - - - - -	-	-
HARDDRAW SCAR { Limestone, earthy - - - - -	15	0
LIMESTONE. { Shale - - - - -	3	0
	{ Limestone, thin-bedded and flaggy	

This limestone occupies the channel as far as a wood west of Needle House, where it contains many corals, encrinites, and some *Producti*. A sandstone dipping W. 27° S. at 7° , here rises from beneath it, and with the strata named in the following section forms a small oblong inlier:—

The Rawthey, near Needlehouse Gill.

	Ft.	Ins.
Hard sandstone - - - - -	about 1	6
Shale - - - - -	0	4
Flaggy sandstone - - - - -	1	6
Shale - - - - -	0	10
Flaggy sandstone and shale - - - - -	5	0
Dark shale - - - - -	1	6
Sandstone - - - - -	0	2
Dark shale - - - - -	0	10
Sandstone, irregular - - - - -	0	1
Dark shale - - - - -	3	0
Hard sandstone (in the bed of the river) - - - - -	-	-

A short distance to the eastward the strata roll over to the east, and the Hardraw Scar Limestone on the south side of the Rawthey, dipping S. 13° E. at 9° , runs down into the bed of the river at the mouth of Needlehouse Gill, and forms a gorge for some distance, the band of shale under its upper bed giving rise to a small waterfall at Uldale Bridge. A dip, increasing to 21° , soon brings the beds above this limestone down into the bottom of the valley.

We get no more clear sections, until at the west end of a wood near Uldale House we find dark shale dipping S. 42° E. at 32° . This is succeeded by flaggy sandstone, containing two thin bands of dark shale, which come down to the river at the next bend in its course, and dip at 32° in a direction S. 28° E. The flaggy sandstone is succeeded by the Middle Limestone, consisting of two members with a dark shale between. Except in a small stream on the west bank we see no more of the limestone along the south side of the Rawthey between this point and a gill east of Hall Intack, which contains loose blocks, supposed to belong to that rock.

Above the Middle Limestone lies dark shale, and above this again flaggy sandstone, dipping S. 35° E. at 36° . The next series of flaggy beds runs down to the river just above Blea Gill. About 40 yards higher up flaggy sandstone dips S. 30° E. at 5° , so that the change in the dip on the east side of the anticline is rapid.

The Rawthey now runs south-east in a gorge cut through sandstone as far as the first waterfall, the strata here lying nearly flat. Finely-grained sandstone continues up to the second waterfall, the Five-Yards Limestone cropping out in the south bank below the fall. At the fall the section is as follows:—

The Rawthey, 420 yards above Blea Gill.

						Ft.	Ins.
Hard sandstone	-	-	-	-	-		
Shale	-	-	-	-	-	0	6
FIVE-YARDS LIMESTONE	-	-	-	-	-	3	6
Hard sandstone, forming the waterfall	-	-	-	-	-	5	7
Soft calcareous sandstone	-	-	-	-	-	3	6
Hard sandstone	-	-	-	-	-		

The following section measured above the waterfall shows that the lower beds of the hard sandstone pass into limestone:—

						Ft.	Ins.
FIVE-YARDS LIMESTONE.	{	Blue limestone	-	-	-	4	6
		Hard finely-grained sandstone	-	-	-	1	8
		Blue limestone	-	-	-	2	0
		Dark limestone	-	-	-	1	6

This limestone is exposed also in Blea Gill and in the road near Uldale House.

Between this and the third waterfall sandstone and flaggy beds, dark and shaly in parts, are well exposed, the valley

having been cut down through a sandstone worked in the Rawthey Gill quarry into these flaggy beds. The lower part of the sandstone is false-bedded, and forms the waterfall. Along the south-west side of the valley and above the waterfall the Underset Limestone forms a line of crags. At this waterfall the following section is exposed :—

The Rawthey, 180 yards above Queen's Stone Gill.

	Ft.	Ins.
UNDerset LIMESTONE, with irregular bands and nodules of chert	-	-
Hard gannister-like sandstone	9	9
Soft sandy underclay	2	0
Hard quartzose sandstone	5	3
Dark sandy shale	4	0
Dark shale	6	3
Sandstone	1	9
Soft yellow shale	3	0
Flaggy sandstone	8	6
Dark shale	2	0
Sandstone, seen to	6	0

In a small stream south-west of this waterfall the Underset Limestone rests on the hard gannister-like sandstone. Here the section given below was measured :—

	Ft.	Ins.
Dark shale	-	-
Limestone?	-	-
Flaggy sandstone	-	-
Hard sandstone with chert	-	-
Dark shale	2	3
Black chert	5	0
Dark shale, a thin band	-	-
UNDerset LIMESTONE, about	23	0
Hard gannister-like sandstone	-	-

A small stream joins the Rawthey about midway between the third and fourth waterfalls. The section of the strata above the Underset Limestone there exposed differs slightly from the one given above.

The Rawthey Valley, 270 yards above Queen's Stone Gill.

	Ft.	Ins.
Dark shale	-	-
Limestone?	-	-
Hard sandstone	-	-
Hard sandstone with cherty bands	9	0
Dark shale	1	6
Hard bastard limestone	2	4
Hard "galliard"	0	5
Black chert	1	4
Hard dark "galliard"	1	10
Dark shale	3	0
UNDerset LIMESTONE	-	-

Above the fourth waterfall the stream flows in a ravine cut out in the Underset Limestone, which here dips S. 10° E. at 4°. The limestone is succeeded by the chert-beds, and these again by a hard sandstone, on the top of which the water runs.

At a southerly bend in the gill a thin band of limestone comes in and continues as far as the more southerly of two small tributaries. In this stream the strata up to the Main Limestone are exposed as follows:—

The Rawthey Valley, 700 yards above Queen's Stone Gill.

	Ft.	Ins.
Coarse grit - - - - -		
Dark shale - - - - -		
MAIN LIMESTONE, junction obscure here; in the neighbourhood - - - - -	30	0
Flaggy sandstone - - - - -	6	9
Dark shale - - - - -	5	0
Black parting - - - - -	0	1
Dark shale - - - - -	3	0
Sandstone - - - - -	10	9
Dark shale - - - - -	13	6
Sandstone - - - - -	8	0
Dark shale - - - - -	9	0
Beds not seen - - - - -		
Limestone - - - - -	2	9

A coal-seam, worked between the Underset and Main Limestones in the Rawthey Valley, west of Holmes Moss, appears to be the same bed which has been unsuccessfully tried on the up-throw side of the fault higher up the valley (p. 67). The number of the adits and the size of the rubbish-heaps at the former place leads us to infer that the seam was of some value there, but no information concerning it could be obtained.

Though the Main Limestone crops out in Coska, Haskew, Nor, and Taiths Gills, it forms no feature along the hill-side between these streams. North of Taiths it is exposed east of Raven Thorn, and also close to the source of Raven Thorn Gill. A line of swallow-holes connects these exposures with those in Slate Gill and other small tributaries of the Rawthey. In one of these the full thickness of the Main Limestone reaches about 30 feet, or somewhat less than in Stony Gill on the east side of Baugh Fell (p. 74). Where the lower part of the Main Limestone forms the sides and bed of the Rawthey the stream becomes very picturesque.

At 100 yards south-east of a sheepfold two small faults, half a chain apart, and with throws of 2 or 3 feet, cross the valley in a direction E. 26° N. About 30 yards further south-east a parallel fault throws the strata down about 20 feet to the south-east, thus bringing the black chert over the limestone down into the channel of the river. Forty yards farther south-east, again, another nearly parallel fault throws the strata down about 40 feet to the north-west so as to bring the Main Limestone up again on the south-east side. In all these faults quartz in finely crystallized hexagonal pyramids with a little copper-ore distributed throughout, forms the vein-stuff. The copper-ore seems originally to have been all pyrites, but decomposition has led to the formation of blue and green carbonates which have stained the vein in a pretty manner. One of the smaller veins.

was tested in a trial-hole, but did not yield nearly enough ore to be worth working. Veins filled with crystallised quartz and bearing a little copper-ore are not uncommon in the Garsdale and Grisdale area and in the country about the head-waters of the Eden and Ure.

The Main Limestone now flanks both sides of the deep valley and gradually runs down into the river at Rawthey Gill Foot. Here its top is clearly seen with a little black chert over it showing an approach to the Swaledale type.

A few trial-pits and levels on the up-cast side of the fault last referred to indicate the presence of a small coal-seam which, however, does not appear to have been much worked. Lower down the Rawthey a coal, occupying about the same horizon, has been rather extensively wrought (p. 66).

(9.) Needlehouse or Uldale Gill.

Needlehouse (or Uldale) Gill joins the Rawthey on the east side of the anticline. For some distance north-eastwards it runs in a deep gorge cut down through the Hardraw Scar Limestone. The dip, at first S. 18° E. at 10°, increases to 15° in a direction S. 10° E., where a hard, calcareous, and quartzose, flaggy sandstone comes on above the limestone. At the foot-path to Needle House a band of sandy limestone or calcareous sandstone, weathering like limestone, crosses the stream. The gill then follows the strike of the rocks, and the water flows on sandstone until a hard quartzose band, 1 foot 6 inches thick, similar to the calcareous sandstone above-mentioned, is reached. This band is overlain by sandy shale containing bands of calcareous sandstone, succeeded by 9 feet of dark shale, which again is followed by sandy shale and flaggy sandstone, with a dip to S. 25° E. at 12°. The dark shale comes down to the bed of the stream about midway between a foot-bridge and the first waterfall, and then begins to rise up towards the north-east. The waterfall is formed by the hard calcareous sandstones, the dark shale lying in the river-bank above. There must, therefore, be either a sharp roll-up or a fault here.

Eastwards the dark shale runs down again into the river-bed, and the sandstone above it forms the second waterfall. Here the dip is S. 27° E. at 10°, while at Uldale Bridge the Simonstone Limestone dips at 15° in a direction S. 38° E. Between Uldale Bridge and the bottom of the first waterfall we have the following section:—

Needlehouse Gill.

	Ft. Ins.	
SIMONSTONE LIMESTONE	-	-
Sandstone	-	-
Shale	-	-
Sandstone	-	13 0
Soft sandstone	-	1 6
Sandstone	-	6 0
Dark shale	-	9 0
Hard calcareous sandstone	-	-
Sandy shale with bands of calcareous sandstone	-	-

The Simonstone Limestone is overlain by dark shale and bands of earthy limestone. Higher up, on the north side of the gill, these limestone-bands come up again and then dip at 17° under dark shale.

Flaggy sandstone continues along the south side of the ravine to the bend in its course between the second and third waterfalls, where it dips N. 33° E. at 21° . It is followed by dark shale, sandy shale, and flaggy sandstone, forming a small waterfall. Above this sandstone are shales with flaggy sandstone, and a hard sandstone which forms another small fall, and has above it a band of earthy limestone containing fossils. The measures over this limestone are not clearly exposed, but a short distance above, a sandstone, containing a thin band of shale, is followed by shaly micaceous beds with thin partings of shale, dipping at 28° in a direction S. 56° E. These are succeeded by a band of earthy limestone at the bottom of the third waterfall, near a small stream from the south, the dip gradually increasing here to 32° , S. 63° E. Above the earthy limestone is a band of shale, 4 feet 4 inches thick, containing a bed of sandstone 3 inches thick. This is followed by a hard sandstone forming the waterfall.

The lower bed of the Middle Limestone comes down at the top of the waterfall. It adheres closely to the hard grey sandstone below. A narrow gorge cut down through the limestone to the sandstone forms the channel in which the brook flows.

The following table gives the sequence of strata from the Five-Yards to the Simonstone Limestone:—

Needlehouse Gill.

		Ft.	Ins.
FIVE-YARDS LIMESTONE.	Limestone - - - - -	5	0
	Hard, dark, sandy band - - - - -	0	9
	Shale - - - - -	0	4
	Limestone - - - - -	4	0
Sandy underclay with rootlets, passing up into limestone - - - - -			
Hard sandstone, &c. - - - - -			
Flaggy sandstone - - - - -			
Dark shale - - - - -			
Flaggy sandstone with bands of shale - - - - -			
Dark shale - - - - -			
Sandstone at fourth waterfall - - - - -			
Dark shale - - - - -			
Flaggy sandstone - - - - -			
Dark shale - - - - -			
MIDDLE LIMESTONE.	Limestone, about - - - - -	12	0
	Dark shale with nodules, about - - - - -	12	0
	Layer of fossils - - - - -	0	$0\frac{1}{2}$
	Dark shale with nodules - - - - -	5	6
	Hard limestone, with encrinites abundant, and <i>Productus giganteus</i> - - - - -	1	0
	Dark shale - - - - -	1	0
	Hard limestone - - - - -	0	3
	Dark shale with thin bands of limestone - - - - -		
Dark shale - - - - -			

					Ft.	Inch.
	Limestone, thinly bedded	-	-	-	-	-
	Limestone, nodular	-	-	-	1	7
	Shale	-	-	-	0	9
	Limestone	-	-	-	1	2
	Shale	-	-	-	2	6
	Limestone	-	-	-	-	-
Hard sandstone with brown spots	-	-	-	-	-	-
Shale	-	-	-	-	1	3
Sandstone	-	-	-	-	0	3
Shale	-	-	-	-	2	10
Hard earthy limestone	-	-	-	-	3	0
Sandstone	-	-	-	-	-	-
Shaly and sandy bands	-	-	-	-	-	-
Sandstone	-	-	-	-	-	-
Shale	-	-	-	-	1	0
Sandstone	-	-	-	-	-	-
Earthy limestone with encrinites and other fossils, passing down into	-	-	-	-	2	6
Hard sandstone	-	-	-	-	-	-
Hard sandy shale	-	-	-	-	2	11
Sandstone	-	-	-	-	-	-
Shale with bands of sandstone	-	-	-	-	-	-
Flaggy sandstone	-	-	-	-	-	-
Sandy shale	-	-	-	-	-	-
Dark shale	-	-	-	-	-	-
Flaggy sandstone	-	-	-	-	-	-
Shale with bands of sandstone	-	-	-	-	2	6
Dark shale with ironstone-nodules, about	-	-	-	-	13	0
Dark shale and bands of earthy limestone	-	-	-	-	1	6
SIMONSTONE LIMESTONE	-	-	-	-	-	-

The dip in the Middle Limestone is S. 56° E. at 35° . Eastwards it continues to increase regularly, and at the flaggy sandstone east of the waterfall reaches 45° to S. 68° E., and still more at the base of the Underset Limestone, where, however, it suddenly changes, and the beds become nearly horizontal, as was the case in the Rawthey (p. 64), without the intervention of any fault.

R. R.

CHAPTER V.—CARBONIFEROUS LIMESTONE SERIES.

—continued.

DISTRICT 2. GARSDALE AND GRISDALE.

The Hardraw Scar Limestone, which plunges down eastwards at Garsdale Foot (p. 43), rises again just above Ingheads Bridge and exposes its whole thickness of 20 feet on the north side of Scar Foot Bridge. It is all hard and compact, and the lower part somewhat siliceous.

Ascending the stream above Ingheads Bridge we pass over some 75 feet of sandstones and shales with two thin beds of impure limestone and reach the Simonstone Limestone. Its outcrop and thickness are not clear; the top consists of rather more than 10 feet of fairly pure limestone, below which lie some 10 feet of flags and shale. At the base is another limestone of doubtful thickness, but not more than 10 feet. On the south side of the dale its course is fairly clear and the whole is seen in Inghead Gill. On the north side the ground is drift-covered but part of the limestone occupies the bed of Garth Gill some 50 feet above the high road.

The Simonstone is separated from the Middle Limestone by about 150 feet of grits and shales which are exposed in many places, both in the main stream and the gills leading into it. A clear section of the strata about the horizon of the Middle Limestone, seen in Garth Gill, gives the following measurements:—

Garth Gill, Garsdale.

								FEET.
Thin flags	-	-	-	-	-	-	-	
Shale	-	-	-	-	-	-	-	6
FIVE-YARDS	{	Red limestone	-	-	-	-	-	3
LIMESTONE.		Shale	-	-	-	-	-	3
		Limestone	-	-	-	-	-	4
Flags	-	-	-	-	-	-	-	20
Shale	-	-	-	-	-	-	-	40
MIDDLE	{	Limestone	-	-	-	-	-	5
LIMESTONE.		Shale	-	-	-	-	-	4
		Limestone	-	-	-	-	-	10
Shale	-	-	-	-	-	-	-	3
Calcareous grit	-	-	-	-	-	-	-	5
Shale	-	-	-	-	-	-	-	2
Flags	-	-	-	-	-	-	-	30
Shale	-	-	-	-	-	-	-	5
Limestone	-	-	-	-	-	-	-	1
Grit	-	-	-	-	-	-	-	5
Shale	-	-	-	-	-	-	-	2
Grits, about	-	-	-	-	-	-	-	40
Shale and grits, about	-	-	-	-	-	-	-	50
SIMONSTONE LIMESTONE	-	-	-	-	-	-	-	

Above Scar House, on the north side of the dale, the Middle Limestone is seen in a small gill and its outcrop may be easily followed to the section in Garth Gill mentioned above, but a few yards beyond this it is completely buried under thick Drift. At Clough it is again well exposed in the beck, its upper part being false-bedded and variable in thickness, while the shale below is fossiliferous; the bottom part of all usually comes off in massive blocks and is characterised here by the presence of many small irregular spots of calcite, as is the case in Swaledale and Higher Teesdale (p. 106). East of Clough the outcrop is entirely covered by Drift or Alluvium until we get to Dandry Mire, near which place there are several small exposures of the characteristic bottom-part of the limestone, in small drains going through the Alluvium.

On the south side of Garsdale a railway-cutting at Ingheads exposes this limestone as follows:—

Railway-cutting, Garsdale.

					FEET.
MIDDLE LIMESTONE.	{	Limestone	-	-	6
		Shale	-	-	4
		Limestone	-	-	5
		Grit (calcareous)	-	-	4
		Limestone	-	-	10

The section of this bed varies much, for in Cat Gill, 500 yards further north, there is more limestone and less shale and grit than in the railway-cutting. The outcrop keeps practically clear of Drift for some distance northwards.

The Middle Limestone is succeeded by about 60 feet of flags and shale, as shown in the section in Garth Gill given above. Above them is the representative of the Five-Yards Limestone, consisting in this district of two small limestones with a shale-parting. Though thin, they are persistent and frequently exposed. On the south side of Garsdale a clear section in Cat Gill shows the following details:—

Cat Gill, Garsdale.

					FEET.
FIVE-YARDS LIMESTONE.	{	Red limestone	-	-	5
		Shale	-	-	5
		Limestone with <i>Productus giganteus</i>	-	-	5

Both these bands appear in Ceaseat Beck, but owing to the thick Drift their further outcrop becomes obscure.

The strata between the Middle and the Five-Yards Limestones, and the latter limestone itself, are well exposed in a gorge 300 yards north of Clough, and also in various sikes on the east side of Grisdale Beck. The sections do not differ materially from those in Garsdale.

The Five-Yards Limestone lies in the middle of a mass of soft shale, which forms a series of hollows in the gills on the

north side of Garsdale. Above these hollows there runs a feature, sometimes a bold scarp, produced by a massive sandstone. The Three-Yards Limestone of the mining districts seems to be represented by a band, from 1 to 2 feet thick, resting on this sandstone. It is rarely visible, but crops out in Rackenthwaite Gill (near Swarth Gill), and in the gill which rises at the Baugh Fell Coal-pits. It also occupies the bed of Ceaseat Beck, just at its junction with Long Gill, for more than 100 yards, but there seems no reason to suppose it to be more than a few feet thick, five at the most. Its top is not at all clear here and the same band of limestone forms the bed of the stream all the way. A little over a mile north of this it crops out at Gabey Hill in Grisdale Beck, but the intervening ground is covered with great masses of Drift.

The Main and Underset Limestones run through Swarth Gill Wood, but are much obscured by the enormous mass of *débris* which has been washed down from the hollow in the hill-side known as Swarth Gill Hole. The Underset Limestone consists of the following divisions:—

Swarth Gill, Baugh Fell.

		FEET.
UNDERSET LIMESTONE.	{ Black even-bedded calcareous shale	3 to 4
	{ Limestone with silicified corals in the upper part	9
Shale	- - - - -	8
Sandstone	- - - - -	4+

At a limekiln in Dry Gill, three-quarters of a mile further west, this limestone is said to be 15 feet thick. The Main Limestone is exposed to a thickness of about 15 feet in a gill 300 yards further east. About 50 feet above it a coal-seam has been worked for more than a mile westwards in a line of old shafts and levels. It occurs also on West Baugh Fell, but the seam below the Underset has been there more extensively sought. The overlying strata, up to the base of the Millstone Grit are concealed by *débris* near Swarth Gill, and can be better studied on the east side of Baugh Fell.

The Underset Limestone from Swarth Gill eastwards has a well-marked outcrop, being in fact accompanied by a continuous line of swallow-holes, till we reach Greenside Quarry, where it is worked as "Black Marble." It is crystalline and of great hardness; and full of crinoid fragments which give it a handsome appearance when polished. The black cheris, so characteristic of this limestone, are well seen here, but only part of the limestone is exposed. It must be at least 10 feet thick, perhaps more, as it forms a considerable spread to the east of the quarry. Swallow-holes mark the outcrop thence as far as Grinning Gill, where the limestone is about 10 feet thick. In a quarry, opened in it a little further to the north-east, it must be quite 15 feet thick and is a fairly pure encrinital limestone. We now

lose sight of it under Drift, until we reach a clear section of both limestone and cherts in Bitter Beck, the cherts being considerably thicker than before. A small seam of coal here crops out some 20 feet below the limestone; but is too thin to be of any economic value. Thick Drift again obscures the outcrop, except in two little streams further north, till we reach a spot, where the clay seems to have slid away from the hill, leaving a bare face of the Underset Limestone. Its course after this is again Drift-covered nor does it come into view in Grisdale Beck.

Near High Ing, however, the scar made by this limestone is quite distinct, and the bed can be carried on west from here by various stream-sections near East House, Fea Fow, Flust, and in the sike south of Nettle Brow. In the same sections the chert and cherty shale above the limestone are also seen distinctly.

The total thickness of strata between the Underset and the Main Limestones is about 80 feet. In a sike not quite a quarter of a mile south of Nettle Brow a thin limestone rests on sandstone, a little above the Underset chert. On Garsdale Common there is a little above the same bed a felspathic sandstone with quartz-pebbles.

Coal has been extensively worked on the top of Garsdale Common at a depth of about 39 feet below the Main Limestone, both by shafts and drifts. In the adjoining Quarter-Sheet (97 S.W.) this coal is still (1883) being worked on a small scale; the thickness in the present workings averages $8\frac{1}{2}$ inches. On the north-east side of Grisdale Beck, by High Ing, and in the sike one-third of a mile north-west of Nettle Brow, various trials for coal have been made at a depth of about 25 feet below the Main Limestone, but apparently with little success.

East of Swarth Gill the outcrop of the Main Limestone is marked by swallow-holes, and here and there by small openings made for lime. Grinning Gill shows the Main Limestone as well as the beds above and below it, as follows:—

Grinning Gill, Garsdale.

	FEET.
Shale	30
Grits and shale	20
Calcareous wedges on grit-bands	15
Shale	25
LITTLE LIMESTONE	3
Grit	3
Shale with a coal-smut at base	25
Shales and grits	50
MAIN LIMESTONE	20
Grit	13
Shale	25
UNDERSET { Chert	2
LIMESTONE. { Shale	5
{ Limestone	10
Grits and shales	

The Main Limestone appears in all three branches of Ceaseat Gill maintaining much the same thickness, but further north is completely concealed by the creeping of the Drift up the hill. A large swallow-hole shows its top just north of Stony Gill, while the whole of it comes into view in each of the three gills to the north. It is at once apparent that a great increase in its importance has taken place, it being here about 40 feet thick. From Shorter Gill the Main Limestone forms a steep scar for some little distance north and still increases in thickness, but the dip, which turns somewhat to the north, brings it again under Drift. At Rawthey Gill Foot and in the stream one-third of a mile west-south-west of Nettle Brow, there are good sections of the limestone. Between High Flust and High Ing, and east of High Ing, the outcrop in the hillside is again quite distinct.

On Garsdale Common it makes a good bare outcrop round the Ordnance Station, 1679. The base-line at the north-east end of the hill is rather indefinite; there are various large masses of broken limestone some distance north-east of the position assigned to it on the map, but they seem all in a more or less shaken condition, and it is doubtful whether any of them are in place. Possibly they are glacially transported masses; the slope of the hill seems hardly steep enough to give rise to landslips in the ordinary sense of the term.

The following is the general section of the strata above the Main Limestone on the north side of Grisdale Beck:—

Grisdale.

	Ft.	Ins.
Fine-grained, compact, flaggy sandstone, probably the		
Ten-Fathom Grit or part of it - - -	25	0
Shale with occasional large calcareous nodules or wedges	120	0
LITTLE LIMESTONE with chert on top - - -	5	0
Sandstone - - - - -	} together from 25 ft. to	50
Shale - - - - -		
COAL - - - - -	-	0
Sandstone or pebbly grit with quartz- - -	} together -	25
pebbles, shale and cherty shale - - -		
MAIN LIMESTONE - - - - -	-	-

The pebbly grit is seen well in the sike one-third of a mile east of Nettle Brow. The coal has been worked at High Flust and from there along the outcrop south-east for nearly a mile by a series of old levels; the thickness is reputed about 8 inches.

The Little Limestone and chert crop out in the sikes that run past Flust and Round Ing, and the chert in the sike east of Nettle Brow. The thick shale that comes on above these makes a great bank-feature all the way from Nettle Brow to the hillside north of East House. The supposed representative of the Ten-Fathom Grit is best exposed in the sike one-third of a mile north of Round Ing.

At the south-east end of Swarth Fell there are no good sections of the rocks between the supposed Ten-Fathom Grit and the base of the Millstone Grit. The only bed that has been traced at all is a strong gannister, which occurs at a distance of perhaps 70 feet above the top of the Ten-Fathom Grit.

Just east of Swarth Gill a considerable number of levels have been driven into the Little Limestone Coal, clearly marking its outcrop. The limestone, with its accompanying hard siliceous bed, makes a distinct feature higher up the hill.

The lowest bed of the 50 feet of shales and grits mentioned in the section of Grinning Gill (p. 73), is a coarse grit characteristic of the horizon at which it occurs. Over a large area this bed, the first grit above the Main Limestone, is almost as full of small pebbles as the basement-bed of the Millstone Grit. The upper branches of Ceaseat Beck show well the whole of these rocks, the Little Limestone being remarkable for its unvarying character and thickness. They are again seen in the three small streams that drain into the upper part of Grisdale Beck. In one of these the Little Limestone Coal has been worked to a small extent for burning the limestone that crops out lower down the hill. At every stream as far as Rawthey Gill, the limestone can be seen, and in that valley the coal also has been worked, a considerable number of levels having been driven into it. On the west side of the valley, the Little Limestone first appears just north of two small faults (p. 66), and from this point it can be traced for about half a mile as far as the two little gills that flow into the Rawthey, west of Holmes Moss. In the more northerly of the two the following section was measured :—

The Rawthey Valley.

						FEET.
LITTLE LIMESTONE	-	-	-	-	-	3
Fucoidal sandstone	-	-	-	-	-	3
Shale	-	-	-	-	-	25
Grit	-	-	-	-	-	5
Shale	-	-	-	-	-	30
Coal-smut	-	-	-	-	-	-
Shale and grits, the lowest grit very coarse	-	-	-	-	-	55

In Slate Gill a flinty sandstone may represent the same bed. On the same horizon in Taiths Gill there occurs a band of limestone. Cherty sandstone and fragments of chert alone mark the position of the Little Limestone in Nor Gill. In Coska Gill a branch of Penny Farm Gill, the Little Limestone more nearly approaches what we find on the east and north sides of Baugh Fell. The section is given in the description of Penny Farm Gill on p. 49.

The Coal-Sills make no distinct feature around West Baugh Fell, but their position is indicated by an almost continuous line

of rubble-heaps along the side of the hill, just above the Main Limestone. The stream-courses show the sills to consist of flaggy sandstone, passing up into grit.

The Little Limestone is overlain on Baugh Fell by about 125 feet of shale with flaggy sandstones in the upper part, the whole being capped on the north-east side of the hill by the Crow Limestone. On the north and north-west sides of Baugh Fell the strata between these two limestones consist of dark shale with three principal bands of sandstone, the features formed by which can be traced for a considerable distance round the Fell.

These strata roughly correspond to the "Crow-beds" and the "Ten-Fathom Grit," of Swaledale and Arkendale. The shales and flags are, owing to their soft nature, constantly cut through all round Baugh Fell. Here and there they contain impersistent calcareous wedges in the upper part, but otherwise call for no special attention. The Crow Limestone can be identified in the upper part of Ceaseat Gill, where it is about two feet thick, but this part of the series lies in a hollow, and is much obscured as far north as the head of Bitter Beck. There it can be seen by fragments of limestone to be resuming its normal character and from this point it steadily increases in thickness until in Red Gill it becomes a fairly pure encrinital limestone, 10 feet thick. It now begins to thin away westward, and in Rawthey Gill is only four feet thick, and so siliceous that it passes into a chert.

In the more southerly of the two small gills west of Holmes Moss, a band of chert, 3 feet thick, seen a short distance below the base of the "Grindstone," probably represents the Crow Limestone. A thin band of dark chert occurs also near the source of Taiths Gill, and black shale contains a thin band of chert in Nor Gill on the same horizon. Penny Farm Gill exposes a sandy limestone, 2 feet thick, and believed to be the equivalent of the same band (p. 53).

Separated from the Crow Limestone by about 30 feet of shale is a gannister, a dense siliceous rock, often as much as 30 feet thick, with a band of carbonaceous matter or a "coal-smut" in the middle. This rock probably corresponds to the "Grindstone" of the country further north, and is important as giving a fixed horizon by which we can check our identification of the base of the Millstone Grit. In Rackenthwaite Gill it is well seen, and a few yards further east there is a trial for the coal in it, but the seam apparently was valueless. East of this the quantity of down-wash becomes so great that the features of the hill are quite obscured, and it is not till the face becomes less steep that the "Grindstone" is again seen. Grinning Gill gives a complete section of this rock showing the coal-smut in the middle. The upper part of the bed is full of the casts of rootlets.

The out-crop of the "Grindstone" now becomes the best-marked feature on the east side of Baugh Fell, and continues

so for a great distance. In the small streams east of Rawthey Gill the lower part frequently consists of flaggy sandstone, but the upper is always dense and hard, and has an almost glassy top. It forms a bold scar just before entering Rawthey Gill. On the south-west side of the river the Drift creeps up the hill above the outcrop of this bed, but does not quite obscure the feature made by it. Emerging from the Drift-cover the rock appears again in a little stream flowing down from the north-east corner of Baugh Fell to join the Rawthey. It is here about 25 feet thick with the usual carbonaceous band in the middle. Thence round the north side of Baugh Fell it forms a distinct feature, exposures of the gannister occurring here and there. East of the source of Nor Gill it makes a well-marked escarpment, but then is lost to view under *débris*. Above the grindstone there lie usually about 30 feet of shale, the uppermost portion of the Carboniferous Limestone Series, which, however, are generally concealed by down-wash from the Millstone Grit.

The beds above the Main Limestone here form a link between the type seen in Swaledale and Wensleydale, and that in the district farther north in the Pennine Hills, where the small coal-seams in the Carboniferous Limestone Series begin to acquire some economic importance.

C. T. C., A. S., G. B.

CHAPTER VI.—CARBONIFEROUS LIMESTONE SERIES

—continued.

DISTRICT 3.

(1.) RAVENSTONEDALE AND UPPER EDEN VALLEY.

Lower Limestone Shales.

These rocks occupy a belt rather under half a mile in breadth on the south flank of Ravenstonedale. They are not to be seen east of the Dent fault which bounds the Silurian Fells, nor indeed for a mile west of it, their probable area here being well covered up with Glacial Drift, but in the stream a short distance above Artlegarth the base of them is well exposed. Here are greyish-green shales, dipping N.N.E. at 15° , and below them a calcareous sandstone with quartz-fragments. This is resting in the stream on green and mulberry-coloured Silurian mudstones which are dipping at an angle of 70° N.N.E., and are much impregnated with brown carbonate of lime which has run into the joints from the overlying Carboniferous rocks. Not a trace of the well-known Basement Conglomerate occurs at this spot. In the same gill below Piper Hole at a higher horizon in the series are brown earthy limestones under black shale, and at the next bend in the stream yellow earthy limestone and shale with corals, crinoids, &c.

Thackthwaite Gill, south of the village of Ravenstonedale, shows in descending order greenish sandstone, black shale, a sea-green clay, and red sandstone, and lying below, but higher up the gill, is red shale.

For a mile west from here no sections are visible in the Lower Limestone Shales, but before coming to the edge of the map we get two very good exposures in Pinskey Gill and Weasdale, especially the former. In Weasdale below the lowest house are Silurian flags dipping vertically and striking east and west, overlain, lower down the stream, by hard sandy grit with black smuts, micaceous shale, and solid mudstones. These are dipping north at about 13° . In Pinskey Gill, north of the road going from Newbiggin to Weasdale are greenish-grey gravelly conglomerates of pre-Carboniferous rocks, and a short distance south of the bridge is seen the following section in descending order:—

Pinskey-Gill.

					Ft.	Ins.
					3	0
					1	
					1	6
					8	0
					5	6
					2	0
					1	0
LOWER LIMESTONE SHALES.					2	0
					12	0
				3 ft. to	5	0
					0	9
					3	0
					1	0
					1	0
					5	0
					2	0
					12	0
SILURIAN ROCKS.						
					65	9

Five or six good sections of the base, extending over two miles of country, bring us to where the Basement Conglomerates come on beneath the Lower Limestone Shales, but there is nothing to warrant us in supposing that they have any existence in the part of the map now under consideration, and certainly it is obvious to an observer on the ground that their non-existence is not due to a fault along the line of junction of the Carboniferous and Silurian Rocks, as was erroneously suggested on a former edition of the Geological Survey Map, but to the Lower Limestone Shales having been deposited on the denuded Silurian surface direct, the red conglomerates being entirely absent. The beds which we have been describing are essentially marine throughout. They contain corals, crinoids, and brachiopods. This is not the case with the red conglomerates and associated sandstones; such fossils have not been found in them nor in rocks of similar appearance and position in other places. The position of these latter, the rapidity with which they come in and die out, their arrangement, and lithological character, consisting almost entirely of pebbles of local rocks, are highly suggestive of their having been deposited in valleys.*

The Great Scar Limestone Series.

Under this heading we include two great masses of limestone separated by a series of shales with limestones and sandstones, which, though unknown in the country around Ingle-

* Possibly river-gravels of Carboniferous age.—R. H. T.

borough, acquires an importance in the north-western part of this district. We may call these three groups in ascending order the Ravenstonedale Limestone, the Ash Fell Beds, and the Melmerby Scar Limestone. They rest on the Lower Limestone Shale and are succeeded above by the Yoredale Series. There are subordinate beds of shale and sandstone at various horizons amongst them, but this is the general succession of the main calcareous masses of the Carboniferous System here.

The chief expanse of Limestone in this Quarter-Sheet lies in the north-west quarter. It is bounded on the south (with the intervention only of the Lower Limestone Shales) by the Silurian Fells. On the east it runs up to the overlying Yoredale Series of the Wild Boar Fell range and across the Eden to the same rocks along the same line of strike. The same overlying rocks just come into the margin of the map on the north, and the irregular triangular area of Permian Rocks lying between Crosby Garret, Wharton Hall, and Hartley, and enclosing Kirkby Stephen, makes an indent into its area along the same edge of the map.

The Ravenstonedale Limestones, the lowest member of the series, are best exposed in Scandal Beck above about and below the village of Ravenstonedale, where from excellent and continuous river-sections, their thickness may be easily calculated. They are here from 1,500 to 1,700 feet in thickness. The lowest beds show in several places a whitish or light-blue grey compact limestone with porcelainous fracture. The Ravenstonedale Limestones are full of fossils; some beds are crammed with brachiopods which give a fissile character to the mass.

We also often get, near the base, yellow, somewhat dolomitic-looking limestones. Grey limestones also occur. About two-thirds up in the thickness of the Ravenstonedale Limestone lies a bed which, though insignificant in dimensions, is interesting as running for some distance, attaining a larger development to the west and being fairly traceable at intervals. This rock which in the Memoir on the Country around Kendal, &c. is described as the Brownber Beds, consists of a horizon along which quartz is abundant, sometimes as fine sandstone, more often as quartz-pebbles, of a coarser material in a matrix of limestone.

The most easterly point where we have recognized it, is in a little brook close to the Sedbergh Road opposite Crooks Beck near Cross Bank. Here may be found traces of a limestone containing quartz-pebbles. It should pass under Bowber Head, and a sandstone occurs at about the same horizon in the lower lane to Ravenstonedale. This seems again to lie on the same horizon as a limestone with quartz-pebbles a quarter of a mile further west in some fields above Claylands. It appears again under a mile to the west in the bluff lying in the fork between Scandal Beck and Couplands Beck and should pass by Friar Bottom, for it is seen in force beneath the railway-bridge, east of Brownber. Here, too, it is a limestone crammed with pebbles of

quartz. Hence to Ravenstonedale Moor Drift comes on and the section is hidden, but in another mile the beds are well seen in small quarries and have been much used for "throughs." Here there are beds of sandstone, above the limestone with quartz-pebbles. For their course hence to Orton the reader is referred to the above-mentioned Memoir.

The Ash Fell beds are well seen in many places as on the Sedbergh Road, and the Ravenstonedale Road, under Ash Fell Edge in Smardale and thence along the escarpment towards and beyond Sunbiggin Tarn. On the Sedbergh Road they show a thickness of between 500 and 600 feet. At least three limestones occur here in the intercalated sandstones and are tolerably thick.

About half a mile to the west of this these limestones appear to be losing character, not thinning out so much as deteriorating into calcareous shales with nodules and sandy clays. About the Ravenstonedale Road the two upper limestones, the thickest in the above-mentioned sections, are only represented by very thin limestones, and there is no trace of the third. In Scandal Beck the limestones are quite insignificant, but the sandstones and grits are in strong force.

At a farm called Bents, one mile north of Newbiggin, the sandstones form a bold broken cliff, and there is a story that their appearance deceived a marauding party in one of the border-raids, who turned back thinking that the masses of rock were houses, and that a village had escaped their foraging and not been sacked.*

Two thin limestones occur north of these well-marked grits under Bents Hill, and further west one of them grows considerably in thickness and covers a broad extent in Rayseat Pike, showing that the westerly dying out of these limestones, if a rule, is not without exceptions.

The conditions which resulted in the intercalation of these sandstones in the great mass of Carboniferous Limestone recur again and again, though in less force, in the great thickness of limestones of Ash Fell and the continuations of the same beds away to Crosby Ravensworth, showing how arbitrary and conventional, if convenient, any sub-divisions in these beds are. One of these beds of sandstone crosses Red Stone Hill between the Sedbergh and Ravenstonedale roads, and gives it its name. Another or the same, being at about the same horizon, lies north of Bents Hill. It is broken by a fault with a downthrow on the west, being thrown to Great Ewe Fell, whence it may be traced down into the valley of Potts Beck, south of Little Asby. Several other intercalated beds of shales or sandstones occur here too between it and the escarpments of the Yoredale Series.

* For those who take an interest in such matters it may be as well to call attention to the very high walls surrounding the "Fold" at Lytheside, a farm house off the Sedbergh Road, which have evidently been constructed with a view to safety on such occasions.

East of the Dent Fault, or where its continuation, if it go so far, may be supposed to come on, we have the following localities where beds other than limestone occur in the Great Scar Limestone area. At Tarn Mire, in a little mound surrounded by Alluvium, a brown sandstone was seen dipping south, but it is doubtful whether it is in place. At Fothergill Close, north of Birkett Tunnel and east of the railway, a red soil lies between two ridges of limestone and seems to indicate a weathered sandstone. Along the ridge Minsefer (called "Mineber" on the map) the limestone is gritty and contains small angular fragments of quartz, the whole being of a red colour. A sandstone interbedded with pink limestone crops out in the Eden near the footbridge south-east of Lammerside Castle. One or two beds of sandstone occur in Thring Gill, above Redding House, in two places with a fault between, and still higher up two more beds, or the same faulted down, are seen in an anticline which is crossed by the stream. On the hill above Lochthwaite, one mile east of Nateby, a sandstone crosses the top of the hill and with the underlying shales has caused a slip to occur.

Yoredale Series.

These rocks form a belt of varying breadth, according to the steepness of the dip, along the east side of the limestone-area, and extend thence along the valleys and across the *cols* between the Millstone Grit Fells.

The base of the Series is much shattered and contorted about the old lead-mines east of Hartley, but a little further south, from Ladthwaite fell-wards, we have an excellent and probably unbroken sequence. The beds it is true are here dipping at first, apparently to the west at high angles, but this is probably only a reversed dip and not a broken series or an anticline. They seem gradually to return from that reversed position to the normal easterly dip and eventually, on the fell-tops, nearly flatten out, and the limestones do not here by their position lend any support to the view that they have been bent over and repeated in an arch, as they do to the north and again to the south. Eleven limestones above the main mass may be seen here on Hartley Fell and along the flanks of the upland valley of Duckerdale, counting up to and inclusive of the Great or Main Limestone.

The lowest four are best exposed in the hill north of Ladthwaite (where some old lead-mines have existed), the third and fourth being thin and close together. From this point it is better to take the Hartley Fell Road to Rollinson's Pits, which in itself forms a section and crosses all the beds. Where the road is out in the open it crosses a limestone obliquely, and further on, where it rises more steeply by a wall, passes two more. These are probably in ascending order the Single Post, Cockle Shell, and Middle Limestones of the rocks.

forming the Pennine Escarpment. Then we cross a wide ridge of sandstone and come upon another limestone, grey, weathering brown. This is probably the Five-Yards Limestone. It is about 15 feet thick. From this point we cross very hard grits again by the shooting-house, and a little further, leaving the road on the south, we may descend the stream to see the following section :—

Reigill, Hartley Fell.

	FEET.	
Grey shale - - - - -	-	
Grit - - - - -	-	30
Shales - - - - -	-	40
Dark limestone (FIVE-YARDS LIMESTONE ?)	-	14
Shale - - - - -	-	5
Grit - - - - -	-	6
Shales - - - - -	-	5
Coal-smut - - - - -	-	0½
Sandstone and shale - - - - -	-	12
Fine-grained sandstone - - - - -	-	8
Coal-smut - - - - -	-	0½
Underolay - - - - -	-	2
Grit - - - - -	-	25
Alternations of flags and shales - - - - -	-	25
Beds not seen - - - - -	-	40
Limestone (SCAR OR MIDDLE LIMESTONE ?)	-	15

129ft.

A thin, limestone thought by Mr. Dakyns to be the Three-Yards Limestone, crosses the beck near the road a little above where this section commences. If this be so, the limestones in this section will probably be as indicated.

Then follow in ascent blue sandy shale and plate and a sandstone, which a little further south in Duckerdale shows a thickness of 60 feet. A little higher up the stream we come to the Underset Coal, which has been worked along the outcrop for some distance to the north but not much to the south. From this point onwards the Underset Limestone is crossed three times by the stream, owing to a fault and a repetition of the bed by an anticline, but an undisturbed section may be seen by following the road. The best sections of the Underset and Main Limestones occur, however, in Reigill above this point to the left of the road, and in Duckerdale to the right of it, where the two scarps follow each other round the hills with picturesque regularity. Between these two limestones a chert appears both in Reigill and in the road, and a coal in the former beneath the Main Limestone. Another coal shows at four feet above it in a pot-hole. The Main Limestone cannot be less than 60 feet thick, and forms a long row of large pot-holes along its upper edge. A 25-foot grit occurs not far above it, and a little higher up, where the stream branches, a red chert is seen. Beyond, grey shales show a considerable thickness and then come two beds of flags, the lower one having a brown gingerbread-like top with fossils in it. Above this a chert should follow, but is

obscured by Drift in the stream. It may be seen in the fell, however, to the north and south of the stream-bed, and another chert is also to be found by hunting about. These two cherts probably represent the Fell Top Limestone, and may be traced for some distance, although from their thinness this is a task which requires careful work.

The Main and Underset Limestones continue round the head of Duckerdale, and the former makes the broad and conspicuous expanse of Tailbrigg. The south side of the higher part of Duckerdale is masked by Drift and "tumble," but there can be no doubt of the range of these escarpments along that side. Tailbrigg is a sloping plateau of bare limestone, forming, in fact, a dip-slope, and at its inner edge the surface-water has made, and drains into, a number of pot-holes which are of considerable depth; some of them probably go through the entire thickness of the limestone, which must be 60 feet. One of them can be entered by the stream-course for some distance, and probably would be worth further exploration. The sides of these pot-holes are beautifully fluted by the dripping of the water from above, and show vertical ridges as sharp as knives.

Two sandstones and a thin limestone occur between the Main and Underset Limestones in the road going down from Tailbrigg towards Nateby, the limestone probably being the equivalent of the chert above-mentioned in Reigill. The Three-Yard Limestone is not visible in the road, but may be traced by pot-holes a little north of it, and probably is indicated by a mossy calcareous spring about 150 yards south of it. In descending by both the gill and the road more limestones may be seen, and a short distance below them a coal has been extensively worked at some time for coke, cinder-ovens occurring on the line of outcrop in places. Two more limestones take us down to the main mass where the boundary must be a fault, for the last of them appears to be turning over by an anticline, and dipping against the main mass. The series, therefore, is not complete here as it is in Rigg Beck and Duckerdale.

At the head of Thring Gill the mass of limestone on Tailbrigg ends off abruptly on the fell, and appears to be thrown by a fault against some sandstones which belong to another horizon. Below them, along the ridge which bounds the south side of the valley, we first pass over a wet interval, probably shales, and then in succession come upon the Fell Top Cherts (two beds), a sandstone, more shales, and then at Green Hill the Main or Great Limestone. The downthrow to the south must therefore be considerable, as will be seen on the map. The fault seems to be running in a west-north-west direction and crosses Thring Gill at a waterfall a little above a sheep-fold, some way below the old coal-workings. A thin limestone is here faulted against a sandstone and is dipping away from it to the south-west.

This fault does not appear to penetrate the main mass of the Great Scar Limestone, but joins or is cut off by the next fault

on the south, which runs through the prominent feature called Blea Combe (spelt Bleakham and Bleakholme on the map) towards the north-west, and from the gill above Carr House takes probably a northerly trend, forming the boundary between the arched Yoredale Rocks already mentioned and the great limestone-tract.

In the ridge of Great Bell, and on the fell going towards Mallerstang Fells End, eight limestones may be seen, including the Main Limestone. The Fell Top Cherts also crop out in the higher part of the series in Southwaite Gill.

The lower part of the Yoredale Series appears to be well continuous from Great Bell to the Eden at Janny Wood, hard by the high road, where the following section is traversed by the stream:—

Janny Wood.

					Ft.	Ins.
Black limestone and shale	-	-	-	-	10	0
Shale	-	-	-	-	4	0
Ferruginous limestone	-	-	-	-	1	3
Black shale	-	-	-	-	15	0
Limestone	-	-	-	-	78	0
Sandstone	-	-	-	-	42	0
Limestone	-	-	-	-	8	0
Hard sandstones and shales	-	-	-	-	20	0
Dark limestone, dipping at 40°; the main mass.						

Four more limestones appear in the little gill which comes down from Southwaite, in continuous order with the above section, but they are not sufficiently well shown to enable one to give measurements. These limestones are, however, fairly well exposed higher up the river, after passing some small faults below Catagill Scar. The river-section indeed for some distance is well worthy of study for its geology as well as its beauty. The best section of these beds, however, is that seen in the Midland Railway from, and south, of Birkett Tunnel. The beds all dip to the S.E., for the most part at 45°. The following are the particulars in descending order in the cutting, commencing near the first bridge over the railway on the south side of the tunnel.

Section South of Birkett Tunnel.

					Ft.	Ins.
Black shale with ironstone-nodules	-	-	-	-	54	0
Limestone, yellow and red at top	-	-	-	-	14	0
Sandstone	-	-	-	-	1	0
Shale	-	-	-	-	5	0
Sandstone	-	-	-	-	7	0
Coal	-	-	-	-	0	2
Shale	-	-	-	-	1	6
Flaggy sandstones	-	-	-	-	22	0
Dark shales with ironstone-nodules, sandy above	-	-	-	-	27	0
Limestone with shaly bands	-	-	-	-	12	0
Sandstone	-	-	-	-	1	0
Limestone	-	-	-	-	1	0

					Ft.	In.
Shales with rippled sandstones	-	-	-	-	9	0
Ironstone with <i>foraminifera</i>	-	-	-	-	0	4
Sandstone	-	-	-	-	4	0
Layers of sandstone and shale	-	-	-	-	14	0
Coal	-	-	-	2 ins. to	0	6
Clayey shale	-	-	-	-	2	0
Nodular limestone-rubble	-	-	-	-	2	0
Limestone with coal-smut at base	-	-	-	-	9	0
Shales	-	-	-	-	4	6
Coal	-	-	-	-	0	4
Sandstone	-	-	-	-	10	0
Shales	-	-	-	-	5	0
Grit with crinoids	-	-	-	-	5	0
Shale	-	-	-	-	2	0
Coal-smut	-	-	-	-	0	4
Shale	-	-	-	-	0	4
Fine earthy sandstone	-	-	-	-	12	0
Shales	-	-	-	-	7	0
Soft grit and shales	-	-	-	-	18	0
Grey earthy limestone with many fossils	-	-	-	-	5	0
Dark shale	-	-	-	-	1	6
Hard sandstone	-	-	-	-	32	0
Hard shales	-	-	-	-	8	0
Coal-smut	-	-	-	-	2	0
Shale and calliard	-	-	-	-	40	0
Gap caused by a fault, downthrow south					*	*
Grit, more than	-	-	-	-	24	0
Micaceous shale	-	-	-	-	0	9
Coal	-	-	-	-	0	2
White underclay-shale	-	-	-	-	1	0
Hard sandstone	-	-	-	-	20	0
Alternations	-	-	-	-	7	0
Hard fine-grained sandstones	-	-	-	-	11	0
Shales	-	-	-	-	7	0
Limestone, grey mottled-orange, weathering in holes at top	-	-	-	-	18	0
Shales with calliard	-	-	-	-	5	0
Calliard-like sandstone	-	-	-	-	4	0
Alternations of grit and shale	-	-	-	-	9	0
Shale	-	-	-	-	9	0
Limestone	-	-	-	-	2	0
Shales with limestone-nodules and pyrites	-	-	-	-	3	0
Limestone, light-grey	-	-	-	-	18	0
Shales and mudstone	-	-	-	-	3	0
Coal-smut	-	-	-	-	0	2
Limestone, earthy	-	-	-	-	1	0
Shales	-	-	-	-	9	0
Nodular limestones with <i>foraminifera</i>	-	-	-	-	1	6
Shale with little nodules	-	-	-	-	3	0
Limestone, light-grey weathering brown, with thin shales in places, large <i>Producti</i> on one horizon	-	-	-	-	60	0
Fine grey shales	-	-	-	-	5	9
Coal	-	-	-	-	0	6
Black calliard	-	-	-	-	1	0
Shales	-	-	-	-	5	0
Calliard and shale	-	-	-	-	16	0
Coal	-	-	-	-	0	2
Shaly grit	-	-	-	-	8	0
Shales	-	-	-	-	3	0
Flaggy grit	-	-	-	-	14	0
Harder flaggy grit	-	-	-	-	54	0
Shales, sandy, micaceous	-	-	-	-	33	0

	Ft.	Ins.
Flaggy sandstone - - - -	5	0
Shales, sandy and flaggy - - - -	5	0
Fine solid freestone, with shale in places	20	0
Black shale, with small nodules of ironstone	21	0
Limestone, grey-brown - - - -	4	6
Black shales with nodules of ironstone	6	0
Brownish-grey limestone - - - -	6	0
Hard shale - - - -	4	0
Thin smut, lying on - - - -		
Earthy limestone with large <i>Producti</i> at top } - 9 ins. to 1	9 ins. to 1	0
Crumbling shale with large <i>Producti</i> - - - -	11	0
Impure limestone, shaly upwards - - - -	2	9
Fine black shale with nodular ironstone - - - -	26 to 30	0
Shaly limestone - - - -	1	0
Shale, fossiliferous - - - -	1	6
Dark greyish-brown limestone - - - -	1	6
Dark limestone, at the Tunnel-mouth, seen to - - - -	12	0

A sandstone occurs in the main mass of the limestone a short way below, and may be seen a little above the southern entrance of the tunnel.

A comparison of the Janny Wood section and so much of the Birkett Tunnel section as may reasonably be supposed to represent it will show how very variable these beds are, the distance between the two localities not being more than three fourths of a mile. We have, indeed, difficulty in recognizing any of the more well-marked beds of the Yoredale Series in the latter section, though the greater part of this series must be represented, as only two more limestones, on the hillside above, intervene between the end of the section and the Great or Main Limestone.

To resume, on the east side of the Eden Valley, south of the great Bleacombe Fault which throws the Main Limestone down on the south a considerable distance (at least as low as the Three-Yards Limestone), this rock seems to run along the side of the valley in a fairly continuous range, only broken by small faults, by Castlethwaite to Outhgill and Birk Rigg. It is interrupted by at least four faults here, which range between west-north-west and north-west. Three are downthrows on the north and one on the south. The Underset Limestone is not seen again on this side of the valley along this distance, being covered up with Glacial Drift and Alluvium, and the Main Limestone itself is often only exposed by reason of its bigness. The beds above, including the cherts, crop up at intervals in reward for a diligent search, and are not, considering their size, so much covered up. In Scar Gill, the northern branch of the stream passing Castlethwaite, we see the following section :—

Scar Gill.

	FEET.
Chert, against a fault - - - -	P
Hard fine-grained sandstone - - - -	7
Shales - - - -	30
Chert-band, thin - - - -	-
Black shales, well shown - - - -	90
Chert with limestone at base - - - -	30

And in the next gill south we have in continuous descending order from this horizon :—

	FEET.
Shale - - - - -	-
Grit - - - - -	25
Calcareous grit with crinoids, seen also in Miregill Sike, half a mile further south - - - - -	7
Micaceous shaly mudstone - - - - -	15

The two cherts crop out at a much higher level in Sloe Brae Gill, whence they range south with an easterly dip to the next fault, but in Stone Close Gill they are descending the stream by a dip-slope.

A big fault with a west-north-westerly trend and a downthrow to the north runs between Birk Rigg and Cranberry, and on the north-east side of Little Fell brings the base of the Main Limestone against, or rather above the topmost of the two cherts. This chert is 30 feet thick with cherty shale above, and below it are sandstones and flags about 30 feet thick. In the gill next north the lower chert shows a thickness of 7 feet, and probably is more.

On the west side of the ridge this fault is much lessened, partly by another ranging north-north-east with a downthrow west, and yet another bearing north with a similar downthrow, which probably cuts it off altogether.

The range of the several cherts and limestones on the west side of Little Fell is better described by the map than by any words. The dip is low at the summit, but increases quickly as you descend, and becomes vertical before joining the Great Scar Limestone. The cherts make well-marked mounds of perished rock with continuous features, and the limestones may be noted chiefly by the ranges of pot-holes on the Moor, and they are sometimes to be seen in the little streams. The upper limestones are fairly continuous and safe to trace for some distance, but the lower and lesser are not easily recognizable from one section to another.

R. H. T.

(2.) MALLERSTANG.

The Main and Underset Limestones are both easily traced along the upper part of Wensleydale, a district known as Lunds, into Westmorland. On the east side of the valley, near Ais Gill, a pair of trough-faults, which are also quartz-and copper-veins, running north-east about 100 yards apart, slightly shift the lines. Thence the Main Limestone can be traced quite clearly as far as Elm Gill, and the Underset nearly as far. But on the north side of the gill both limestones are found outcropping at a much lower level. The beds are evidently thrown down to the north by a fault running east-south-east. Eastward the massive grits that form the southern part of Mallerstang Edge

end abruptly at the slack north of High Rigg. Thus we get a good general direction for the fault hereabouts, which points for the same slack on the County-Boundary, a little north of Scarth of Scaithes, as a fault running up Sleddale points for; but the fault must change its direction eastward from east-south-east to east north-east.

On the west side of the Eden we find equally good evidence for the fault in the abrupt termination of the Main and Underset Limestones. Both of these beds are well seen from the south up to the latitude of Hall Hill and Hazel Gill, where we find the beds thrown down to the north along a line which requires but a slight curve to bring it into coincidence with the direction of the fault on the east side of the river. This line trends west north-west from Hall Hill to High Dolphinsty, a conspicuous nick in the fell. On the south side of this line the Main Limestone is found on Little Wold more than 1,500 feet above the sea, and on the north side the same bed is at the level of the railway, about 1,000 feet above the sea.

The Main Limestone is overlain by black shale, sandstone, and chert. These beds are well exposed in Hell Gill and in two small gills (one of which is called Joseph Gill) flowing from the moorland on the east side. The succeeding beds are buried in Drift along the course of Hell Gill; but at the elbow, 200 yards above the spot where the County-Boundary leaves the stream, a thin limestone crops out, which we suppose to be the Crow Limestone.

In Joseph Gill and the other small gill we see a strong but thin sandstone above the cherty shales. This may represent the Ten-Fathom Grit. Over it we have shale in which a small fault runs north-east, *i.e.*, parallel to the other faults. Higher up we see nothing but peat till we reach the Rigg. At the north end we find flags dipping south-east at 10° ; and several blocks of gannister are lying about on the Rigg. We therefore suppose this to be the outcrop of the bed of gannister that lies below or forms the lower part of the Ingleborough Grit. Immediately north of the copper-veins, sandstone lies beneath the Main Limestone, and north of Slade Edge the Underset Limestone has a basement sandstone. At Hanging Lund the underlying beds consist of shale on a thin limestone on sandstone, the thin limestone being probably the Three-Yards.

West of the Eden all the gills give good sections. Above Angerholme the lower part of the gill exposes only Till. The upper part shows black shale up to 60 feet under Till, and then the Underset Limestone. Above it is a thin shale, a thin limestone, and then more shale; then a sandstone on which rests the Main Limestone. A similar section occurs in Bank Gill, except that here we see a considerable mass of sandstone below the Underset Limestone, and that the little limestone above it is partly chert. In the railway-cutting near this place, barely half a mile north of Angerholme, a limestone, overlain by shale, may

be referred to the Five-Yards, but it cannot be traced owing to Drift. The Main Limestone forms a fine escarpment; its base bends round owing to a sharp rise of the beds as we approach the fault, and is slightly hitched by a few cross-veins, containing some copper-ore. The most northern of these faults breaks through the Millstone Grit of Wild Boar Fell.

The beds overlying the Main Limestone are obscured, north of Ais Gill, by masses of slipped and tumbled rocks from the scars of Wild Boar Fell, but in Packers Gill we get a section showing chert and then a thin limestone and over that calcareous plate and shale. A feature over the spring at the head of the gill looks like the escarpment of a rock, probably the gannister-like grit or quartzite, which was noted on the ridge south of Dolphinsty.

Close to the fault at Dolphinsty we see, some way above the Main Limestone, a strongish sandstone, on which lies a thin limestone beneath shale, above which is another sandstone and then fossiliferous cherty beds. Above these comes the bed of quartzite or gannister-like grit. These beds cannot be traced far southward, as they soon get quite covered with the *débris* from the higher scars of the fell. There is no true Glacial Drift, but quite down to the limestone the ground is strewn with scattered blocks of grit, which must either have been ice-borne or else have slid down on snow from the scars above. The beds mentioned above are also to be seen, as well as the Main Limestone, at the head of Scandal Beck.

Below the outlier of Millstone Grit of Little Fell we cross, on the descent into the Eden valley, flags and shale in Fool Sike. A little farther north, at Grey Stones, a bed of gannister, which cannot be traced south up to the fault, evidently corresponds to the gannister or quartzite that occurs 100 feet below White Walls (*see above*). The next section is in shale below the gannister, but it is only below the grainings that we get anything like a continuous section. Here we have at the sheepfold in Deep Gill a bed of calcareous mudstone and chert, which also forms Ling Hill a little further north. Below the chert we see in one or other of the gills called Deep, Cowstead, and Long Gills, shale with a thin fossiliferous limestone at its base, and then a thin layer of flagstone, the sole representative hereabouts of the Ten-Fathom Grit. Below the flagstone there comes shale with thin layers of chert on limestone, and then sandstone and shale immediately over the Main Limestone, the base of which crosses the railway close to Long Gill, rising north. The Underset Limestone and intermediate beds, including a thin limestone, are visible at Hazel Gill, but further north these lower beds are quite hidden by Till. Immediately south of Hazel Gill a fault throws the beds down to the north-east, but the ground is rather obscure.

On the east side of the river the Underset Limestone crops out above Elm Gill close to the big fault, and also above Thrang

Bridge, but between these spots is quite hidden by Till. The Main Limestone appears in Crag Gill and Great Gill, overlain by chert, and in Knowes Sike there is a good section of the rock with sandstone below it at Thrang Force. Hence the outcrop or the bed northward is marked by great swallow-holes as far as Wether Hill, where it is thrown down to the north by a fault running north-west and south-east. This fault is clearly seen to break the grits of Mallerstang Edge and to cross the County-Boundary at a spot called Gregory Chapel.

J. R. D.

CHAPTER VII.—CARBONIFEROUS LIMESTONE
SERIES.—*continued.*

DISTRICT 4.

(1.) THE VALLEY OF THE URE (WENSLEYDALE).

This valley, under the name of Yoredale, is so well known from the writings of Prof. J. Phillips that we shall content ourselves with giving a few details. The higher beds which form the watershed between Wensleydale and Swaledale belong to both districts alike and will be described later on. The following general section gives the thicknesses of the beds in the upper part and on the south side of the dale :—

	FET.
Shales - - - - -	60 to 120
MAIN LIMESTONE - - - - -	60
Sandstone and shale - - - - -	35 to 20
Coal, 8 to 4 inches - - - - -	$\frac{1}{2}$
Sandstone and shale - - - - -	60
UNDERSSET LIMESTONE (upper part dark and cherty) - - - - -	20
Sandstone and shale - - - - -	100
Yellow limestone - - - - -	5
Sandstone and shale - - - - -	70
Crinoidal limestone - - - - -	1 to $\frac{1}{2}$
Flags and shale - - - - -	50
FIVE-YARDS LIMESTONE, productal and yellow in the upper part - - - - -	9
Strong flagstones } - - - - -	100
Shale with fossils }	
MIDDLE LIMESTONE. { Limestone - - - - -	6
{ Shale with fossils - - - - -	3
{ Limestone - - - - -	15
{ Thin parting - - - - -	2
{ Spotted limestone - - - - -	8
Sandstone and shale - - - - -	12
Occasional dark and impure limestone - - - - -	$1\frac{1}{2}$
Sandstone and shale - - - - -	5
Coal - - - - -	$\frac{1}{2}$
HAWES { Sandstone and shale - - - - -	35
FLAGS. { Limestone - - - - -	$1\frac{1}{2}$
{ Sandstone and shale - - - - -	70 to 80
SIMONSTONE LIMESTONE - - - - -	20 to 30
Shales and sandstone with two thin limestones - - - - -	40 to 60
HARDRAW SCAR LIMESTONE, sometimes in two beds - - - - -	50
Sandstone } - - - - -	
Shale with ironstone }	80 to 100
GREAT SCAR LIMESTONE, with a shale-parting near the top and a sandstone near the lowest part seen; exposed to about	100

The Hardraw Scar Limestone is well seen in the bed of the stream called Whitfield or Mill Gill (north-west of Askrigg) from Slape Wath to Mill Gill Force, where the water is precipitated over the basement-beds of this limestone and underlying black shale. Compact yellow, fine-grained sandstones beneath receive the falling water, and on the east bank form a cliff, which has been quarried to some extent and used for building purposes. Thorngill Force, at the head of Thorngill's Grove, occupies a similar geological position at the base of the Hardraw Scar Limestone, which eastward crops out in the road at Lea Gate leading from Askrigg into Swaledale. Eastward this limestone forms a fine terrace from Newbiggin, Nappa Scar, and Woodhall Mill, the high road following its strike, and nearly defining its lower boundary. The junction with the underlying beds is well seen in the scar above Newbiggin Beck, below the road, and near Nappa Hall.

Following the Hardraw Scar Limestone westwards from Mill Gill, we find it thick-bedded and quarried at Spen House; a small cave occurs in the rock below the road and the Gill Keld well issues from the base of the limestone. In Skell Gill the limestone in the beck is jointed and much shaken; westward it makes a bold escarpment known as Shaw Cote Scar, nearly a mile in length. The upper boundary of the limestone is defined by numerous swallow-holes, and the lower rests in the escarpment on a sandstone, a few feet down in which numerous springs issue. Westwards by Litherskew and Sedbusk sections are not numerous, but many swallow-holes occur, and the limestone is often seen to rest on a sandstone.

This is best exposed at the celebrated waterfall known as Hardraw Force, where the united streams of Fossdale and Hearne Beck fall over a scar formed by the limestone and its basement-sandstone, with a gorge cut out of the underlying shales, thus affording a very good section of the beds. The same limestone forms Cotter Force also, in the Cotterdale Beck, westward from which point it becomes entirely covered up by Drift.

The Simonstone Limestone comes well into sight east of Askrigg in Newbiggin Beck, near Horrabank House, and in Whitfield Gill below Whitfield Gill Force. About 30 feet below the base of the limestone there is a band, 2 feet 6 inches in thickness, of very compact limestone of a dark colour and breaking with a conchoidal fracture; it is exposed in the bank above Slape Wath, where the bridle-road crosses the beck. The Simonstone Limestone is also well seen in Skell Gill in the bed of the stream, above the farm of that name, and again in Mease or Maze Gill and in its escarpment above Litherskew, where it is very fossiliferous. Thence it can be easily traced by Low and High Shaw, above the hamlet of Simonstone, to Fossdale Beck. It is laid bare in Cotterdale Beck also, but westward from that place is quite concealed by Drift on the north side of the Ure. But on the other side of the river in the beck just above Mossdale Head it is fully exposed,

with a thin limestone below it crossing the stream by the bridge. Between the two comes a strong sandstone largely quarried in the construction of the railway. In the map neither of these limestones have been carried on west owing to the great thickness of Boulder Clay in this direction.

In the same beck a limestone, $1\frac{1}{2}$ feet thick, between the Simonstone and the Middle Limestones, is seen at a point about 100 yards above the head of the plantation. The distance below the Middle Limestone is probably 50 or 60 feet.

The Middle Limestone comes well into view both in Whitfield Gill and also in Sargill, as the upper part of Skell Gill is called. In ascending the latter gill from the Simonstone Limestone, 75 feet of shale with a few sandstone-bands are passed over, and we come to a dark-coloured limestone about 2 feet thick, over which there are between 75 and 100 feet of shale and sandstone underlying the Middle Limestone. A large number of springs issue from this rock. It is much traversed by joints which are wide and open and were probably filled with vein-stuff, to obtain which some old levels enter the hill near the old lime-kiln. There is also a good section in Mease Gill, the beds from the Middle Limestone downwards being seen in the following continuous sequence :—

Mease Gill.

	Ft.	Ins.
MIDDLE LIMESTONE	48	0
Sandstones, shales, and flags	20	0
Coal	0	10
Sandstones, micaceous flags, calcareous shales, and shales	148	0
SIMONSTONE LIMESTONE	25	0
Shales and massive sandstone	25	0
Shales with calcareous bands		

Immediately west of Mease Gill is the large cave called the Mease Holes, the entrance of which is in the top-bed of the Middle Limestone, and descends some distance into the hill-side. Thence the Middle Limestone can be easily traced to Fossdale Beck. The coal in connection with it was recently being worked above Sedbusk, where it was from 8 to 14 inches thick. West of Fossdale the lower beds are much obscured by Drift; but the Middle Limestone crops out on the east side of Cotterdale from the hamlet to Black Rash Wood. Immediately west of Cotterdale it is quite buried in Drift, but it appears again about the Moor Cock (near Hawes Junction), where the coal below it was formerly extensively worked.

On the south side of Mossdale Beck also this coal, 18 or 19 feet below the limestone, has been extensively worked; the thickness here is not known. About 5 feet above the coal is a thin, dark, impure limestone. In the railway-cutting one mile west of Thwaite Bridge (Wensleydale) the coal is about 6 inches thick; it seems at first to be lying in gentle anticlines, but this

appearance is really due to the varying thickness of the beds between it and the Middle Limestone; the base of the limestone keeps nearly level all the time.

There are good sections of the Middle Limestone in the sike that runs between the "w" and "C" of "New Close Allotments," and in Great Gill and Dry Beck. The top part is separated from the middle by three or more feet of fossiliferous shale, and the lower part is characterised by the presence of many small irregular spots of calcite (*see also* p. 71). In Great Gill the shale above the Middle Limestone is full of fossils and contains nodules and thin courses of impure limestone.

Between the Middle and the Five-Yards Limestones (the "Fourth Set") there are usually thick good flagstones, corresponding to the Lower Brigstone Hazle of Alston Moor. They have been extensively quarried in Great Gill and in the sides of the sike alluded to.

There are good sections of the Five-Yards Limestone in Great Gill, and the two gills next east, and in one a third of a mile slightly east of north of Hillary's Hut. The upper part generally weathers very yellow; the lower part is crowded with *Productus*. The total thickness averages perhaps 10 feet.

In the sike alluded to there is a band of crinoidal limestone about 70 feet below the Three-Yards Limestone (the "Third Set"). The thickness varies from 6 inches to 1 foot, and there is shale both above and below. The same bed is seen in the gill that comes into Great Gill a little above the "G" of "Gill."

As a rule very little of the Three-Yards Limestone is seen, and its position is often doubtful. There is an exposure, however, in the sike alluded to in the New Close Allotments, and in the one that comes into Dry Beck by the "y" of "Dry"; in the last place it is greatly decomposed into ochre, and cannot be more than a few feet thick.

In Wensleydale on both sides of the river two sets of flagstone have been extensively quarried, viz., those corresponding to the Lower Brigstone Hazle mentioned above, and also those corresponding to the High Brigstone Hazle. The finest quarries in these flagstones lie on the north side of the river a little east of the road from Hawes to Muker. The surfaces of the flags here worked show some peculiar impressions, which have been described by Professor W. C. Williamson under the name of *Protichnites Davisi*.*

The Three-Yards and Five-Yards Limestones both crop out in Johnstone Gill north of the Moor Cock and also above the hamlet of Cotterdale. They are both seen in Fossdale but cannot be satisfactorily traced. The latter comes into view in Sedbusk High Pasture; and finally both appear in Sargill. Here the section of the Five-Yards Limestone is limestone 2 feet

* "On some undescribed Tracks of Invertebrate Animals from the Yoredale Rocks." *Mem. Manchester Lit. and Phil. Soc.* for 1884-85. The fossils were discovered by Mr. C. E. De Rance.

6 inches, on shale 6 feet, on thin limestone forming a cap to sandstone.

The Underset and Main Limestones, as a rule, make such splendid escarpments throughout Wensleydale as generally to be quite unmistakable, and the map shows better than words can tell the run of the beds. We merely give a few details.

In Mossdale, the only portion of the country south of the Ure which occurs in this map, the Underset Limestone does not make a prominent band, but its position is fixed by various gill-sections at a height of about 1,450 feet on the hill-end south of the word "Mossdale." The top is dark and cherty. There are traces of coal 30 or 40 feet below the base of the Main Limestone just outside this map, at the head of the gill that runs into Great Gill by the "ll" of "Gill." This is no doubt the same seam as that worked further west on Garsdale Common. The seat of the coal is a strong sandstone, the upper part of which contains quartz- and felspar-pebbles. The Main Limestone, on the same hill-end, is partly covered with tumbled blocks which obscure the base to some extent.

There is a good stream-section in Goodham Gill, on the west side of the Ure at Shaw Paddock, from the base of the Underset up to the supposed representative of the Fell-Top Limestone. In this section, and also in the next gill to the south, a little limestone rests on sandstone, a little above the top of the Underset; the exact thickness is not clear. Twenty feet below the Main Limestone there is a fireclay, but no coal is visible. The chert and "Red Beds"—impure limestones, weathering yellow—above the Main Limestone are seen very well, and just above these is the horizon for the coal that has been worked so extensively near High Flust in Grisdale. The base of the supposed representative of the Ten-Fathom Grit is somewhat indefinite, the flagstones getting gradually more thinly bedded and mixed with shale as we go down in the section. Above the top of the sandstone we get about 20 feet of shale, and then the thin cherty limestone, which we suppose to represent the Fell-Top Limestone of the country further north.

The Main Limestone is well exposed at Red Nook Quarries at South Lund Pasture, where it is underlain by thin shale and a coal-seam, which was formerly worked at Gibson's Pasture. The Underset Limestone crops out at High Shaw Paddock and in the quarries to the north.

One of the best sections of the entire series of beds from the base of the Underset Limestone to the coal-seams above the base of the Millstone Grit occurs in the gill running from the Old Coal-Pits above Lambfold Crags to Lunds Church. Above the terrace of Drift, which extends up to Shaws, the Underset Limestone is seen to be exceedingly cherty in its upper portion, and to be overlain by shales with a coal-seam about 5 inches in thickness; above this occur about 20 feet of fine-grained sandstone. The stream above is precipitated over the lower beds of

the Main Limestone in a picturesque waterfall. At the sheepfold above the "High Way," a mountain-road which follows the upper boundary of this limestone for a considerable distance, the following section occurs:—

Lunds Fell.

							Ft.	Ins.
Black shale -	-	-	-	-	-	-	20	0
Black chert -	-	-	-	-	-	-	0	7
Limestone -	-	-	-	-	-	-	2	5
Gannister -	-	-	-	-	-	-	1	10
Black shale -	-	-	-	-	-	-	2	0
Rippled flags	-	-	-	-	-	-	8	1
Black shale -	-	-	-	-	-	-	2	1

Black shales are deeply cut into by Scars and Lambfold Gills, bands of flaggy sandstone being numerous, and ironstone-nodules, some of large size, occurring in the shales. These beds underlie a band of calcareous yellow sandstone, weathering into holes, above which come black shales with isolated nodules of calcareous sandstone, overlain by the rather massive jointed grit, which forms Lambfold Craggs, and can be traced to the Grass Gill Crag to the north-north-west.

In Dove Gill, above High Dike, south of the Lambfold sections, 20 feet of shales overlie the Main Limestone, and are overlain by a few feet of rippled flags, on which rest 2 feet 3 inches of dark limestone; above occur about 100 feet of black shale with yellow fine-grained sandstone. The shales last seen are highly disturbed, but appear to be overlain, at the sheepfold, by a highly fossiliferous chert, above which comes compact grit with occasional quartz-pebbles. Above the sheepfold the fault, ranging north-north-west through Johnstone Gill, repeats the chert-bed higher up the stream, and throws the base of the Millstone Grit further to the north, on the east side. The ascending series above the Little Limestone in this gill consists of about 100 feet of black shale with sandstone-bands near the base, underlying Millstone Grit.

If we follow the Main Limestone from the watershed between the Eden basin and the Ure, down the valley traversed by the latter river we find its base at the following levels above the Ordnance datum:—

Height of the base of the Main Limestone in Wensleydale above the sea.

	HEIGHT IN FEET.	THICKNESS IN FEET.
Jingling Hole, Hell Gill - - -	1,250	90
South Lunds Pasture - - -	1,400	—
The High Way, Thwaite Bridge Common -	1,500	80
Seavy Sike Force, West Gill, Cotterdale -	1,350	—
Hearne Top, east entrance of Cotterdale -	1,590	65
Waterfall, Fossdale Beck, - - -	1,475	60
Pike Hill, Abbotside - - -	1,640	85
High Clint - - -	1,650	—

The Main Limestone north-west of Askrigg occupies a considerable extent of ground on Whitfield Fell and Stack Hill, its base forming the scars known as High Scar on the west and Ball Fell Scar on the east. About 20 feet above it there occurs a bed of limestone which can be traced continuously from Seavy Gutter southward to Whitfield Fell, and thence northward by Black Hole and Lealamb Pot to the fault or "land-slide" known as Red Braes fault. On the west side of the fell this little limestone is cherty; but on the eastern side, on the slopes overhanging the *col* between the Oxnop and Askrigg valleys, it is pure and white, as it is also on Satron Brow at the opposite side of Oxnop Gill. Cherts and Red Beds and shale occupy a space nearly three-quarters of a mile broad between the top of the Main Limestone and the base of the Ten-Fathom Grit on the south side of Blackstone Edge, and within this space there occurs an outlier of the Ten-Fathom Grit, capped by shale and a small tract of pebbly Millstone Grit, measuring 160 yards from north to south, and 60 yards in breadth.

North-east of Askrigg the Underset Limestone forms the escarpments called Ellerkin Scar and the Combs. The outcrop is only 50 yards wide in places at the first locality; but at the Combs, where the beds are rolling, it occupies a breadth of about 200 yards. The Main Limestone also, which has been quarried on both sides of the road from Askrigg to Summer Lodge, forms a well-marked and picturesque escarpment on the margin of Woodhall Moor. The deep indentation called Crowe Knot Nick, following the line of the Mount Pleasant fault, affords a good opportunity of examining the rock. The base-ment-beds are mainly made up of corals to a thickness of 10 or 12 feet. Both limestones are well seen going east, where they spread out a good deal on a slope dipping to the south; but the lower limestones are much obscured by Boulder Clay. Several small veins, however, mostly running north-north-west, have been proved and worked in this south-east corner of the map.

At Windgate Greets three distinct bands of limestone, pierced by many swallow-holes, some of which are 28 feet in depth, occur above the Main Limestone. At Fleak Well a bed of flags, probably representing the Ten-Fathom Grit, immediately underlies the pebbly Millstone Grit, and throws out the water. The flags are well exposed also at Long Band close to the road; but at Whirley Gill Head on the southern side of the water-course they are not to be seen. Thus there is reason to think that in this neighbourhood the Crow Limestones and the Ten-Fathom Grit almost, if not entirely, die away. About half a mile west of Long Band a 10-inch coal was once worked in the shale under the flags.

(2.) THE WATERSHED BETWEEN WENSLEYDALE AND SWALEDALE.

At the eastern edge of the map the pebbly Millstone Grit occupies a large area over the Fleak and Beldon Bottom; but along the south-eastern margin of the map sections of the beds above the Main Limestone are very poor, all being hidden beneath widespread peat and Drift, and thus the base of the Millstone Grit in Beldon Bottom is uncertain; but there can be no great thickness of the rock.

Some interesting sections are observable in the sike coming down from Beldon Mouth to Bleaberry Hole; the apparent base of the pebbly grit is reached, and a bed of black shale is seen containing a coal-seam 10 inches in thickness which is worked from headings driven into the side of the hill; the shales beneath this coal, when followed eastward to Sod Dyke Nick, are found to rest upon the Crow Cherts; but in the Smelting Gill, the corresponding space is filled with another bed of pebbly grit, which forms the massive escarpment called Scar Brow. This pebbly grit dwindles away eastward, and in a small outlier, resting on the Crow Cherts, reaches only a few feet in thickness. Following the Smelting Gill down, we find pebbly grit resting on the Ten-Fathom Grit with a mere trace of the Crow Limestone between them. Below the yellow, rather fine-grained sandstone of the Ten-Fathom Grit series are the usual dark shales.

The fine mass of fell which is known as Oxnop Common, and culminates in Blackstone, is an outlier of the Millstone Grit. It terminates north-westwards in Stony Gill Head, a narrow gorge, exhibiting on both sides interesting sections of the pebbly grit, Crow Limestones, Ten-Fathom Grit, and the cherty bands of the Red Beds. The Ten-Fathom Grit can be traced entirely round Blackstone, and consists of compact grit with occasional flags; from Stony Gill Head to Seavy Sike Gutter it is overlain by a very white limestone, on which rests the pebbly grit; on the eastern side of the Fell, the beds intervening between the Ten-Fathom and pebbly grits consist of Crow Limestone, earthy and passing into cherts, overlain by shales.

On the long eastern slope of Blackstone lying between the outcrop of the Ten-Fathom Grit and Oxnop Gill, the structure is complicated by a line of fault or sharp change of dip or both, which has repeated the outcrops of the Red Beds and Ten-Fathom Grit and thrown down the outlier of pebbly Millstone Grit known as Red Braes. This line of fault ranges north-north-west and passes immediately north of Lealamb Pot, a large swallow-hole, where a thick bed of limestone is exposed, dipping to the north-east. The ground still further east by Oxnop Gill is a good deal obscured by landslips, no doubt due to the easterly or north-easterly dip.

Westwards from Stony Gill Head the presence of the white crystalline Crow Limestone is indicated by swallow-holes at Black Pot Head; thence westward the pebbly Millstone Grit rests directly on the Ten-Fathom Grit, which crops out above Tom Pratt Sike and Ruth Boggy Wells. Westward the pebbly grit is seen in the bed of White Sike in Roundfold Gutter, and in the sike between the two, and also in Cogill Beck near the intersection of White Beacon Gutter. Between the base of the grit and the top of the Main Limestone, the sections in this tract are obscure, being covered with Glacial Drift. South of the Black Bank Shooting Box, the Ten-Fathom Grit, consisting of thin-bedded sandstones, appears at the base of the pebbly grit. It is next seen in Dry Gill, where it is separated from the pebbly grit by about 11 feet of shale, and from thence westward it can be traced round Stags Fell, overlying shale, cherts, and Red Beds.

The Ten-Fathom Grit occurs as fine-grained flaggy sandstones separated by bands of shale at Sod Hole Gill, with black shale both above and below it. Further south 8 or 10 feet of flaggy sandstone appear in the gill which runs down from Lower Millstones to Pike Slack. From this section it can be traced by means of occasional loose fragments through and around the low hill called Bleak Haw, which is capped by an outlier of pebbly Millstone Grit.

A large mass of fell, west of the Buttertubs pass and south of the Stockdale vein, lies between the upper part of Wensleydale and Swaledale, and, forming Abbotside and Angram Common, culminates in the Great Shunner Fell, 2,340 feet above sea level.

For convenience of description we limit this district on the north by the Stockdale vein, which runs across Angram Common. The position of the vein is fixed in the following manner. The Underset and Main Limestones can be traced round the fell from Cliff Beck to Thwaite Beck by means of features and of swallow-holes. Just above Cliff Beck, and close to the high road from Muker to the Hawes, there are in the Main Limestone several very large swallow-holes of great beauty, known as the Buttertubs. But on the north side of Thwaite Beck both limestones end abruptly along an east and west line against the Stockdale vein, the position of which is thus fixed.

A small area containing outcrops of the Main and Underset Limestones exists in Great Sleddale on the south side of the Stockdale vein; but there is nothing special to be said about these exposures of limestone, except this; here we find the Underset Limestone to be immediately overlain by sandstone; this is unusual among the Yoredale beds, in which the general rule is that limestones are overlain by shale.

The beds above the Main Limestone are very changeable and many points connected with them are obscure. We will therefore

describe the sections somewhat minutely. We begin with the beds in Stockdale immediately south of the fault, so as to work continuously round the hill with the sun.

In Caw Gill immediately above the Main Limestone we have a thin bed of chert overlain by shales and these by flags. The flags we consider to be the Ten-Fathom Grit. They are overlain by a thick bed of shale in which is a thin sandstone. In Thwaite Beck the section is as follows: Above the Main Limestone we have shales, near the top of which there is a thin, calcareous, cherty bed. Then come flaggy shales and sandstone with a fossiliferous top, showing *Cauda galli*, which forms a waterfall. This sandstone we correlate with the Ten-Fathom Grit. In the shales above the waterfall there is a thin limestone and a little higher up a bed of gannister, and then a grit next flaggy shale and then a thick bed of grit, which forms a good feature running up to Whetstone Rigg. These two grits form good features across Thwaite Common, but become obscure before we reach Grainsy Gill.

In the grains at the head of this gill, however, we get good sections, as follows: Shale over the Main Limestone with some chert; and then a thick mass of sandstone and shale, which corresponds to the bed we have been calling Ten-Fathom Grit. There is a thin limestone in these beds near the top, and another at the top of the sandstone. About 25 feet higher up we have a gannister-like grit with pebbles, and about 25 feet above it a thick bed of coarse grit. These beds evidently correspond to the gannister and grit of the previous section.

Howgate Edge consists of grit on sandstone and corresponds mainly with the pebbly gannister; but owing to the great amount of *débris* on the hillside, it is uncertain whether the Ten-Fathom Grit is represented by the lower part of Howgate Edge or is entirely hidden. On the east side of Cliff Beck, however, we have a clear section in Long Scar. Here we have pebbly grit on shale and coal, on pebbly grit, on shale, on limestone, on sandstone. The sandstone at the bottom is the bed we have been calling Ten-Fathom Grit, and here, too, we have distinctly seen the little Crow Limestone, which generally marks its top. The overlying pebbly grits are considered by everybody to be Millstone Grit, and there can be no doubt that the lower one corresponds to the coarse grit on the top of Ingleborough.

In Fossdale over the Main Limestone we have chert and a thin limestone, and then a considerable thickness of shale, and then our Ten-Fathom Grit, in the shape of a thick bed of flaggy sandstone. Its base is exposed to view at the first waterfall above the Main Limestone. A calcareous bed forms its top. Immediately above it comes the pebbly grit of Howgate Edge.

The beds deteriorate rapidly north-westward, for in the next gill beyond the Cotterdale Coal-pit, Long Gill, the ascending section above the Main Limestone is: Shale more than 50 feet thick, then the Ten-Fathom Grit represented by flaggy shale

with a little sandstone, and then more shale; the total thickness of strata between the limestone and the Millstone Grit being rather over 150 feet. In East Gill the Ten-Fathom Grit is a mass of flaggy sandstone and shale. In the overlying shale there is a thin fossiliferous Crow Limestone. Westward all is obscure, and the Ten-Fathom Grit cannot be traced at all, which is not surprising, as it consists of shale as much as of sandstone. It does not show at the surface in West Gill, its place being hidden by thick Till. The Crow Limestone is unusually thick and is underlain by a sandstone with *Cauda galli*.

Quite at the head of Great Sleddale, due north of West Gill, we have above the Main Limestone a thick bed of shale with a little sandstone. Above the shale there comes a bed of flagstone, which answers in every respect to the Ten-Fathom Grit. In the overlying shales there is a band of fossiliferous limestone. A little higher up we have a thin gannister-like sandstone; then a thick bed of shale and calliard; and over the shale a bed of flags succeeded by a strong grit, which forms Lady Edge. It is obvious that the fossiliferous limestone is the Crow Limestone of West Gill; and the gannister-like sandstone is probably the hard sandstone of Coal Force; but if so, the overlying shales are here much thicker than in West Gill. The flags and grit evidently correspond to the pebbly grit. Tracing the beds eastward, we find the gannister in Adam Gill with the overlying flags, but the grit is not seen.

In Stackers Gill we get a good section above the Main Limestone; to wit, a thick mass of shale containing a thin limestone; then the Ten-Fathom Grit with a thin limestone on its top; then shale, and a sandstone corresponding in position with the gannister; then shale and sandstone. A similar, but fuller section, is seen in the grains of Watery Gill, especially in that descending from Daddy Mea Edge, and in Brian Grain. The section above the Main Limestone is as follows: Shale and ironstone; sandstone (the Ten-Fathom Grit) with a thin limestone on or near its top; shale; grit and sandstone; coal; shale; sandstone; thin shale; sandstone, on which lies a fossiliferous limestone; shale; sandstone with *Cauda galli*; thick shale and then the sandstone of Brian Grain Edge (=that of Pickersett Edge). Between Brian Grain and Great Sike the ground is obscure and the sections are not quite parallel. Over the Main Limestone we have cherty shales and then the usual Ten-Fathom Grit; then shale with a thin gannister, which we could not trace; and over the shale a pebbly grit and breccia, forming a seat to a coal; then shale and more pebbly grit; then more shale and a double bed of gannister-like sandstone; then shale again and then a bed of pebbly grit; then grit and sandstone; shale; flags; thick shale, and finally the grit of Shunner Fell Rake. This brings us round to where we started from, as the next gill is Stockdale. The correlation of the beds which we have attempted is exhibited in a tabular form on p. 146.

J. R. D., C. E. R.

CHAPTER VIII.—CARBONIFEROUS LIMESTONE SERIES—*continued.*

DISTRICT 5. SWALEDALE.

THIS portion of the district extends from a mile above Keld to the eastern margin of the Quarter-Sheet. The geological structure is not as a rule hard to make out, owing to the prominence and comparative constancy of character of the different limestone-bands. The sandstones and shales are usually less to be depended on, but even these, excepting when we get up into or just below the Millstone Grit, seem to be more constant than is the case in some districts. The map shows the different bands of limestone with such clearness that we deem it unnecessary to to describe their courses in detail. We shall, however, notice the positions where they show most prominently, and their chief variations in thickness and character.

A little way within the adjoining Quarter-Sheet 97 N.E. two streams near together on the south side of the Swale come down from Whitaside Moor, which give most excellent sections, perhaps the best in the whole dale; the Hardraw Scar, the Middle, and the Main Limestones, are particularly well seen.

Perhaps the most important fault in Swaledale is that known as the Stockdale Fault, described in detail on p. 171. This enters the eastern margin of the sheet about a mile north of the Swale, and runs rudely east and west. It has a large downthrow to the north, with the effect that the three lowest limestones mapped in the dale are nowhere seen within this area on the north side of it.

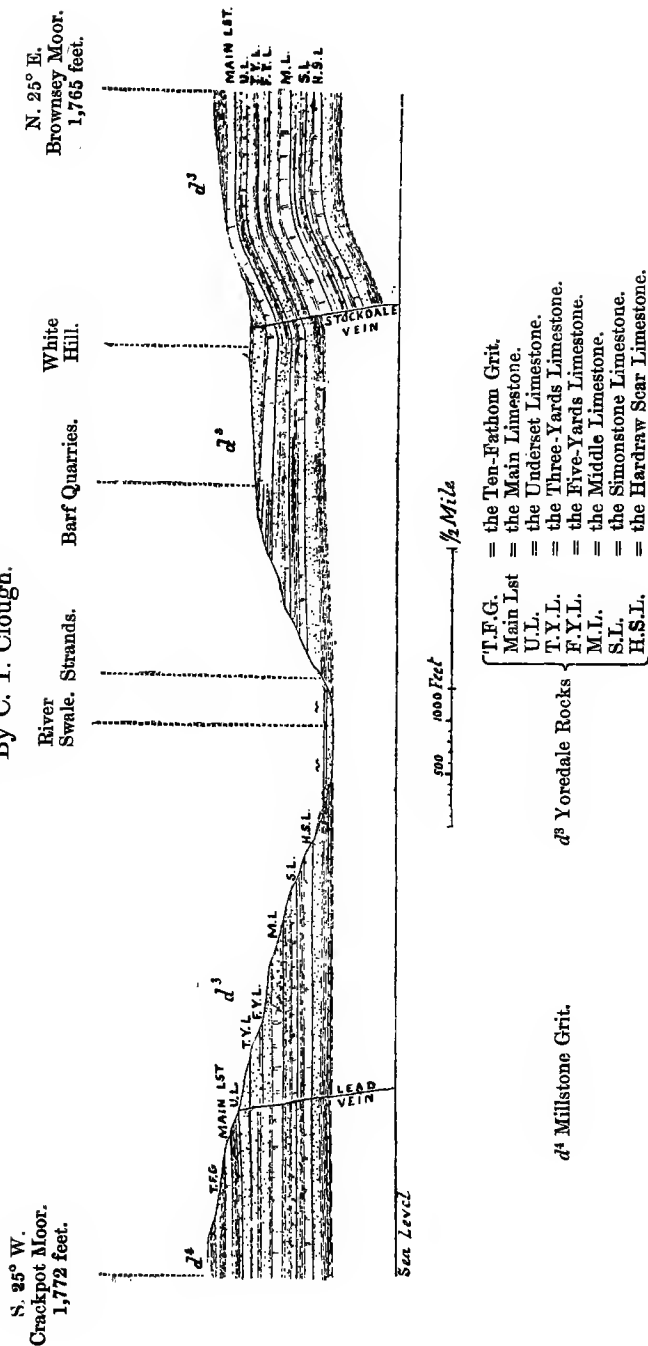
The lowest limestone seen anywhere in Swaledale, whether in this sheet or not, is that below the Hardraw Scar Limestone. It is exposed in two localities only, viz., in Gunnerside Beck close on the east side thereof, at the upper end of the village, and in the bed of the Swale half a mile west of Gunnerside. The beck-section shows the limestone bent into a rather sharp anticline with shale in the centre. It is not improbable that a little way below the shale comes more limestone, but nothing is actually seen below it. The limestone-top is not definitely shown, but we may, perhaps, estimate the thickness as 25 feet. The shale as far as seen is about 6 feet thick. In the Swale west of Gunnerside only the top of the limestone appears. The limestone may, perhaps, directly underlie the Alluvium and terrace-gravel which spreads out on either side of the foot of Gunnerside Beck.

The beds of sandstone and shale that come between this and the Hardraw Scar Limestone are well exposed in Summer Lodge Beck, on the south side of the Swale opposite Gunnerside, on the banks of Gunnerside Beck a little above the village, in Ivet Beck on the south side of the Stockdale fault, and in Cliff Beck

FIG. 11.

Section across Swaledale.

By C. T. Clough.



by Scar House. Opposite the foot of Gunnerside Beck, and between this locality and Spring End, the thick sandstone below the Hardraw Scar Limestone has been largely quarried. Below this sandstone in the river-scar opposite the beck-foot, there are at least 40 feet of shale seen with half-inch nodules and courses of ironstone; the base is not reached.

The two limestones next above, viz., the Hardraw Scar and the Simonstone, run as a rule not far from horizontally, save near faults, all the way from half a mile west of Summer Lodge Beck to Thwaite Beck. Immediately on the west side of the first-mentioned beck their outcrops, and also those of the next three limestones above, are so entirely obscured by Boulder Clay that we have not mapped them. The "band" of the Hardraw Scar Limestone is particularly prominent just opposite the foot of Gunnerside Beck, and a few hundred yards east of Spring End. It forms the lowest limestone outcropping on the north side of the Swale between Gunnerside and the eastern margin of the map, but it is not usually so evident here as on the south side of the Swale. On the same side of the Swale west of Gunnerside it is largely Drift-covered, and for this reason we have not always connected the different exposures. It makes a scar on the top of the gorge 200 yards north-north-west of Gunnerside village bridge, and is again seen on either side of Ivelet Beck south of the Stockdale fault. Further west still it is exposed in the north bank of the Swale three quarters of a mile below Muker, and on the edge of the Alluvium one third of a mile east-north-east of this village. The lower part of the limestone comes into the Swale for a little space above the foot of Oxnop Beck, and then, owing to the dip changing into an easterly direction, comes out again at a point about a quarter of a mile above the foot of the beck. There are good sections in the limestone in Oxnop Beck near the bridge, in Cliff Beck 100 yards above Scar House, and at the waterfall above Haverdale Mill in Summer Lodge Beck. The average thickness is, perhaps, 50 feet, but it is certainly more than this near the eastern margin of the map between Gunnerside and Low Row. In a quarry 200 yards south of Gunnerside Beck-foot some of the lower "posts"* of the limestone are false bedded.

There are several thin limestones below the Simonstone Limestone and it may be remarked that this is also the case with the Tyne Bottom Limestone of Alston Moor and Higher Teesdale with which this limestone undoubtedly corresponds. They are well seen in Oxnop Beck and Routin Gill. In the latter gill there is a 7-inch coal under the little limestone next below the Simonstone, and in Coal Sike—a sike close east of Greensat Gill—a coal on much the same horizon has been worked on a small scale.

The outcrop of the Simonstone Limestone is particularly distinct on the dale side opposite Gunnerside. Indeed this is the

* A North-Country term for beds.

case with all the mapped limestones in the dale excepting the lowest one below the Hardraw Scar Limestone; from some of the cottage-windows in the village it is possible to see them all at once. Perhaps the best beck-section is in Oxnop Beck 300 yards above the bridge. The average thickness may be estimated at 25 feet.

The flaggy sandstones under the Middle Limestone are particularly strong in Thwaite and Cliff Becks, and have been largely worked by levels and quarries in the latter locality. In both these becks, too, there are, at a distance of 50 or 60 feet below the limestone, various thin limestones and calcareous sandstones. They are best seen in Thwaite Beck a little below the "e" of "Moor Close," but the section here is faulted. The top bed is a good limestone perhaps 2 or 3 feet thick; below this comes an impure limestone 12 or 18 inches thick with a gannister-post above and a calcareous sandstone about 3 feet below.

Near Spring End a 2-inch coal lies a few feet below the Middle Limestone. A 6-inch coal occurs also a little below in Cliff Beck and in a sike that comes into this beck from the south east (east of Thwaite quarry).

The Middle Limestone forms a readily traceable band on the south side of the Swale all the way from 300 yards south-east of Spring End to Oxnop Beck, in which beck there is a good section; also on the north side of the dale from a little west of Barf End to the eastern margin of map. In some places it is as thick as the Main Limestone, but it is really composed usually of three parts separated by thin divisions of shale and sandstone. Near Low Row the total thickness is sometimes about 70 feet, but further west it gets thinner and perhaps the average in the dale generally does not exceed 45 feet. In the level just above the high road a quarter of a mile east of Rowleth Wood it was proved to be about 60 feet. On the north side of the Swale between Barf End and the eastern margin of map it forms three features on the hillside, separated by thin partings of shale and sandstone. On the east side of Oxnop Beck also its outcrop presents the same character. As a rule the upper part is a good grey limestone and averages perhaps 25 feet in thickness. The middle part is darker and less pure-looking. The lower part is again a good grey limestone; it is about 8 feet thick, weathers usually in massive blocks, and is marked by the presence of many small irregular calcite spots of doubtful origin. These characters correspond so well with those of the Scar, the Cockleshell and the Single Post Limestones of Upper Teesdale, Alston Moor, &c. that we do not hesitate to correlate the parts of the Middle Limestone with those bands. To show the change that has taken place in the beds between these areas, we give below the average section of them as found in Upper Teesdale within Quarter-Sheet 102 N.E.

Equivalents of the Middle Limestone in Teesdale.

						FEET.
SCAR LIMESTONE -	-	-	-	-	-	22
Sandstone and shale -	-	-	-	-	-	30
COCKLESHELL LIMESTONE -	-	-	-	-	-	5
Sandstone and shale -	-	-	-	-	-	11
SINGLE POST LIMESTONE -	-	-	-	-	-	10

In Cliff Beck and Thwaite Beck it is not clear that any parting exists between the upper parts.

The Middle Limestone is the lowest bed seen on the north side of the Stockdale fault. It occurs in two localities on this north side, viz., in Gunnerside Beck half a mile or so above the village, forming an inlier, on the downstream side of which upper beds come in owing to a dip in this direction steeper than the fall of the beck, and in Ivelet Beck close on the north side of the fault. In Gunnerside Beck the upper part of it is false-bedded and full of *Productus*.

Between the Middle Limestone and the one next above there is usually a thick bed of good flagstones corresponding to the Lower Brigstone Hazle of Alston Moor, &c. They have been extensively quarried in Low Row Pasture.

A few feet below this next limestone there is in Gunnerside Beck a one-inch coal. The limestone (the Five-Yards Limestone of the earlier chapters) is by some miners called the "fourth set" and by others the "third," the latter passing over the thinner yellow limestone above without a name. In Swaledale it is usually a good grey limestone not specially characterised by *Productus* (as it is in its lower part in Wensleydale) and averages perhaps 20 feet, though sometimes it may get up to 30 feet. It does not usually make much show on the hillside, as the strong sandstone close above tumbles over and greatly obscures the outcrop. It is, however, quite clear on the dale-side south of Gunnerside Beck Foot, between this locality and Gill Head, and on the north side of the Swale half-way between Barf End and Brownsey House. There are also good beck-sections in Gunnerside Beck near the "u" of "Gunnerside Gill," and in Ivelet Beck south-west of Shoregill Head. In the last-named beck there is a parting of about 3 feet of fireclay and shale within it.

The sandstone that comes a little way above this limestone and which, as already said, so frequently tumbles over and hides its outcrop, no doubt corresponds to the Upper Brigstone Hazle of Alston Moor. There are several large quarries in it up Gunnerside Beck.

The next limestone, the Three-Yards Limestone of the earlier chapters of this book, is, strictly speaking, the "third set," counting downwards from the Main Limestone. It makes a bare band in one place only in the dale; this is slightly east of south of the foot of Gunnerside Beck, and at an elevation of

about 1,400 feet. There are good beck-sections in Gunnerside Beck a little above the first "G" of Gunnerside Gill," and again further up the same beck about a quarter of a mile below Blakethwaite Smelt Mill, a position to which the limestone is thrown up by a fault. Other sections occur in Ivelet Beck 250 yards west-north-west of Shoregill Head, and in Cliff Beck. The thickness is generally about 10 feet, and the rock weathers yellow. This is much its character in the Alston Moor and Upper Teesdale district where it is commonly called the Three-Yards Limestone. In Cliff Beck it is only 4 feet thick and has sandstone both above and below it. In Ivelet Beck it lies between sandstones. We may remark here again that such a succession is unusual in the Carboniferous Limestone series, the almost invariable rule being that limestones are underlain by sandstones but overlain by shales.

The flags and shales between this limestone and the Underset are seen particularly clearly near the foot of the east and west gill south of Lownathwaite Mines. They are here excessively false-bedded.

In Hard Level Gill there is a one-inch coal on gannister immediately below the Underset Limestone. A little below Kisdon Force—on the Swale half a mile below Keld—a smut of one or two inches in thickness occupies a similar position; the gannister below is excessively hard and compact and rests with an irregular base on a clayey sandstone. At the foot of Swinner Gill the same hard gannister is seen clearly, and below it, about 20 feet below the limestone, is a one-inch coal on fireclay.

The Underset and the Main Limestones generally occupy higher ground than the beds already mentioned and are consequently less frequently obscured by Drift; at the same time they are so thick and so close together that they can hardly be mistaken anywhere. The thickness of the Underset varies perhaps from 20 feet to twice that. The Underset Chert is of very variable occurrence. Where most strongly developed there is still generally an admixture of impure limestone near the top, *e.g.*, in Gunnerside Beck. At other times it is mixed throughout with lumps and bands of limestone in about equal proportion to itself, *e.g.*, at Hooker Mill Scar (Kisdon), and there is some doubt whether it should be included with the limestone or not. In the locality mentioned it has not been included. On Muker Side, Satron High Walls, and at the Old Gang Smelt Mill there is little or no chert. In the last two cases the change from chert to limestone appears very rapid.

In Oxnop Beck and on the east side of Ivelet Beck the Main and Underset Limestones are unusually near together, but the thickness of the parting is not known exactly. At "Fairy Hole," too, a quarter of a mile south of Summer Lodge, the two limestones are almost in contact, though in the closely adjoining

Bloody Vale the parting, consisting chiefly of sandstone, is about 40 feet thick.

Scarcely a quarter of a mile west of Greenseat Gill there are a coal and fireclay immediately under the Main Limestone. They rest on a gannister. A little south of the south-easterly gill (West Arngill) east of Kisdon, a two-inch coal is also seen about 2 feet below the limestone. In West Arngill a gannister, $4\frac{1}{2}$ feet thick, comes immediately under the limestone, but no coal was observed.

The base of the Main Limestone on the hill south of Gunnerside runs at a height of between 1,500 and 1,600 feet. On the west side of the Oxnop Gill disturbances the base is rather higher. It forms a broad running round Kisdon which is prominent on all sides, excepting for a little space opposite Thorns and between this locality and the foot of East Gill, where it is almost entirely Drift covered. The dip on Kisdon is generally northerly or north-north-westerly, so that the height of the outcrop on the south side of the hill is much higher than on the north; on the south side it varies between 1,500 and 1,600 feet, and on the north side between 1,000 and 1,100 feet. Between Arngill and Keld the dip is north-east at angles of 3° or 4° , and much the same as the slope of the hill, so that the outcrop must cover a considerable area, but it is chiefly covered by Boulder Clay. On the north side of the Swale between East Gill and Swinner Gill the outcrop is a double one, being repeated by the "Hurrace Vein" (see p. 176) which downthrows to the south. In Swinner Gill itself it is exposed three times in the stream-bed owing to faults with a prevailing southerly downthrow; the lowest exposure occurs south-west of the Smelt Mill, the middle one almost due west, and the highest 200 yards north-west of the mill. From Swinner Gill to a little below Muker on the north-east side of the Swale the scar made by the Main Limestone is very prominent, and the same is the case in Gunnerside Gill, particularly near the head of the gill, and on its eastern side along Winterings Edge and in the High Scar a quarter of a mile north-east of Whin Hall. On the east side of Gunnerside there is, on the north side of the Stockdale Fault (see p. 171), a steep southerly dip of the beds into the fault, so that the outcrop of the Main Limestone descends to a much lower level close to the fault than it is a little further north. In the valley of Hard Level Gill it is not usually seen very well, owing to the widespread covering of Drift. It, however, comes twice into the stream, the highest exposure being between the Old Rake Hush Vein on the south and the North Rake Hush Vein on the north, these two veins throwing here in opposite directions.

The thickness in the Swale one mile west-north-west of Keld and in the beck that comes between the "K" and "e" of the "Keld" of "Keld Side" (Blackburn Beck) cannot be much over 40 feet, but in most parts of Swaledale it can justly claim the name of Twelve-Fathom Limestone so often given it. Nodules

of chert are occasionally found within the mass of the limestone, e.g., near the base in the east and west gill, south of Lownathwaite Mines.

Average section of the Swaledale Carboniferous Limestone Series between Low Row and Keld, from the Main Limestone downwards.

	Ft.	Ins.
MAIN LIMESTONE - - - - -	60	0
Sandstone and shale - - - - -	25	0
Occasional coal - - - - -	0	8
Sandstone and shale - - - - -	25	0
UNDERSET CHERT, varies from - - - - -	0 to	20
UNDERSET LIMESTONE, varies from - - - - -	20 feet to	40
Sandstone and shale - - - - -	120	0
Limestone - - - - -	10	0
Sandstone and shale - - - - -	75	0
Limestone - - - - -	20	0
Strong flagstones and shale - - - - -	110	0
MIDDLE LIMESTONE - - - - -	45	0
Sandstone and shale - - - - -	20	0
Occasional coal - - - - -	0	6
Sandstone and shale - - - - -	35	0
Limestone - - - - -	2	0
Sandstone and shale - - - - -	60	0
SIMONSTONE LIMESTONE - - - - -	25	0
Sandstones and shales with several thin limestones - - - - -	60	0
Sandstones and shales - - - - -		
HARDRAW SCAR LIMESTONE - - - - -	50	0
Sandstone and shale - - - - -	150	0
Limestone - - - - -	25	0
Shale, base not seen - - - - -	5	0

On top of the Main Limestone there is usually a mixed series of cherts and impure limestone-bands which go by the name of the Main Chert, and there is some doubt which line to take for the top of the limestone proper. As a rule, it is in this area taken below these bands. In some places there is also above the Main Chert another cherty series separated therefrom by shale. Parts of this series may consist of a yellow crumbly-weathering crinoidal limestone, which are called "Red Beds," and other parts of blacker cherts, &c., called "Black Beds." It appears that the "Red Beds" usually come above the "Black Beds," but we do not know that this order is universal.

North of High Kisdon a grey crinoidal limestone, a little above the Main Limestone, forms a prominent band for half a mile or more. On Satron Moor also a limestone on about the same horizon is well seen between the Stottergill Mine and Scar Band; at the latter locality it has been worked in several quarries.

In the part of Swaledale at present being described, no sandstone is known between the Main Limestone and the Ten-Fathom Grit, excepting in the Stonesdales, on Kisdon, and half a mile east of Keld. On Kisdon the sandstone is seen but obscurely; it occurs near the top of the limestone, is fine-grained

and rubbly in texture, and contains plant-remains. On the north side of a "hush,"* half a mile east of Keld (Beldi Hill Hush) there is a sandstone about 6 feet thick, about 20 feet above the line taken for the top of the Main Limestone. In East Stonesdale the shale below the Ten-Fathom Grit contains thin courses of clay-ironstone.

The Ten-Fathom Grit is the only sandstone in the Carboniferous Limestone Series which we have generally mapped, as in the lower part of the series the limestones are themselves quite sufficiently numerous to indicate the geological horizon of any place, and they are generally much more readily traceable than the sandstones owing to the swallow-holes which occur along the outcrops, even if covered with some thickness of Boulder Clay. In this area its course is therefore at once evident in the map, as it is the only bed of the series coloured as a sandstone. Between Stottergill Mine and Summer Lodge Tarn there rise here and there through the peat several eminences, such as Great Bull Head and Little Bull Head, which are outliers of the Ten-Fathom Grit, and consist chiefly of flags. The Ten-Fathom Grit forms an outlier on Kisdon, but the base here is not very definite. The show made on the hillside is much more satisfactory on the east side of the Swale east of Kisdon, and in Summer Gill. The outcrops on the west side of the Angram valley and in West Stonesdale, though in some places probably unusually broad, are not seen well owing to Drift. In the upper part of West Stonesdale a small inlier commences at the foot of Tan Gill and extends up to about half-way between Mould Gill and Lad Gill (north of Mould Gill), where the cherts above once more enter the stream; the grit here is mostly flaggy and soft. The Ten-Fathom Grit by no means always attains the thickness implied by its name. On Muker Common it is doubtful whether the thickness ever exceeds 30 feet, and on Crackpot Moor it is also abnormally thin in places. In Ivelet Beck it is, on the other hand, considerably over 60 feet, and probably throughout the north side of the Swale it is more often over 60 feet than under. It seems also to be abnormally thick on Kisdon. In some places, *e.g.*, in Gunnerside Gill, it is divisible into three parts, a lower flaggy and shaly, a middle massive or flaggy, and an upper gannister. The upper gannister makes a strong scar on the south side of West Arngill Head a quarter of a mile north of the Arngill Head, marked on the one-inch map. Near the Blakethwaite dams there is a 3-inch coal in it. In East Gill, which comes into West Stonesdale Beck from the west by the "1" of "Stonesdale" Beck, and on the fell one mile north-west of Thwaite, it contains casts of shells besides rootlets. The parting between the upper and middle divisions often consists of limestone or of limestone and chert, *e.g.*, in Hind Hole Beck, in the east and west gill by Swinnergill Mines, and on Raydale Side.

* For an explanation of this term see p. 166.

In the east and west gill south of Lownathwaite Mines the limestone is dark and ferruginous, and probably only about $1\frac{1}{2}$ feet thick. In East Gill it is scarcely 1 foot, but there is also a calcareous sandstone a little below; under the sandstone there is on the east side of the gill a 2-inch coal on fireclay. It is often a matter of doubt, *e.g.*, in East Stonesdale, where to take the base-line of the grit, for the local flag-bands near the bottom strengthen and die out again rapidly.

The beds between the base of the Millstone Grit and the top of the Ten-Fathom Grit are very different in different localities. On Crackpot Moor (south of Gunnerside) the total thickness between them is ordinarily less than 50 feet, but the details of the beds are not clear. On Muker Common the thickness is still less, often only a few feet, and in some places it is possible even that there is no parting at all; at the head of Greenseat Gill the parting is about 7 feet and mostly shale. In Lover Gill it is as follows, beginning from above:—

	FEET.
Coal, a few inches	-
Shale	2
Fireclay and gannister	$1\frac{1}{2}$

We cannot be certain though, that this fireclay and gannister may not represent merely the top of the Ten-Fathom Grit so often seen on the north side of the Swale.

With these sections the general section in Stonesdale is in striking contrast. It is somewhat as follows, beginning from above:—

Strata between the Millstone Grit and the Ten-Fathom Grit in Stonesdale.

	Ft.	Ins.
Shale with half-inch ironstone-courses	110	0
Shale with ironstone-nodules		
Impure cherty limestone	0	10
Shale	5	0
Coal, trace	-	-
Fireclay or gannister	10	0
Shale with ironstone-nodules	50	0
Limestone, impure (UPPER FELL TOP LIMESTONE?), varies from - - - - - 1 ft. to	3	0
Shale	25	0
Limestone, impure (LOWER FELL TOP LIMESTONE?), varies from - - - - - 1 ft. to	3	0
Shale with ironstone-nodules	35	0?
Crow Chert and cherty limestone		

It can scarcely be supposed that this great thickness is due to the upper part of the section being contemporaneous with what is elsewhere included in the Millstone Grit, for, though in some parts of Stonesdale there is little or no pebbly grit below the Tanhill coal, still there is a thick development of it at the head of Potshaw Gill (the gill opposite Lad Gill), and the

shales below are not much, if at all, thinner than usual. Such an explanation, therefore, can at most only account for part of the change, and we must conclude that most of the change is due to the oncoming of fresh beds between the base of the Millstone Grit and the top of the Ten-Fathom Grit as we advance northwards from the south of the Swale.

The proportion of chert in this Stonesdale section is much less than usual in Arkendale or most of the rest of Swaledale north of the Swale, and it seems as if the chert has been replaced here to a large extent by masses of shale with a few hard calcareous bands. The two lower bands of limestone noted in the section probably represent the Fell Top Limestones of the district further north. The upper band is sometimes compound; the two parts of it lie close together in Dover Hole Sike, and the lower part can be followed to Tan Gill, where it contains flattened casts of *Posidonomya* (?). About 30 feet below is another shaly, hard, calcareous band, and 30 feet below this again the Crow Chert. On the opposite side of the dale, in Thomas Gill, these shales form a bold scar in which the following section is seen :—

		Ft.	Ins.
Shale	- - - - -	-	-
FELL TOP LIMESTONE?	{ Limestone with casts of <i>Productus</i>	1	0
	{ Shale	1	6
	{ Cherty bed	0	9
Shale	- - - - -	25	0
Cherty bed	- - - - -	3	0
Shale, to base of section	- - - - -	-	-

In Potshaw Gill there are again two Fell Top Limestones, each barely 1 foot thick. In the west bank of East Gill by a sheepfold rather over a quarter of a mile below the Gill Head there are various thin clayey limestone-courses, which probably represent the Fell Top Limestone.

The fireclay (or gannister) varies in character. Quite at the head of the dale it is merely a small underclay with a coal-smut above. In Tan Gill also it shows this character: below the Low Level there are two small underclays, but it is probably the lower one of these that is the most persistent. In Lad Gill it resumes its character of a thin, hard, gannister-like bed, cropping out just below where the old road crosses. In Mould Gill (south of Lad Gill) it is partly a fireclay and partly a hard dark sandstone with rootlets. In Thomas Gill, on the west side of Stonesdale, it has lately been exposed in a shale-gorge; it is a thin, flaggy, and gannister-like bed hardly 1 foot thick with a coaly base. At the south end of the hill between Raven Seat and West Stonesdale, the gannister thickens considerably, and, as it occurs in the midst of a mass of shale, makes a peculiarly sharp feature known as "Crack Band." Round the south end of Black Moor, and on the east side of East Gill about a quarter of a mile below East Gill Head, it again makes a strong feature.

In the last-named place there is again an impure limestone just above it, and also an upper fireclay 30 feet above.

The Crow Limestone is usually represented in West Stonesdale only by cherts, but at the foot of Tan Gill a kind of wedge of the typical encrinital limestone occurs. The chert is seen in Thomas Gill a little above the sheepfold, in Stonesdale Beck some distance above the bridge, and in some quarries west and south-west of the bridge. The best exposure, however, occurs in Mould Gill (north of Lad Gill) close to a new coal-road, where the chert is quarried for road-metal.

The Crow Limestone in Mould Gill.

							Ft.	Ins.
Shale, about	-	-	-	-	-	-	30	0
Chert	-	-	-	-	-	-	1	9
Shaly beds	-	-	-	-	-	-	5	0
Chert	-	-	-	-	-	-	7	0

In Gunnerside Gill the following is the general section from the Millstone Grit base downwards:—

								FEET.
Coal	-	-	-	-	-	-	-	30
Gannister or fireclay	-	-	-	-	-	-	-	
Shale	-	-	-	-	-	-	-	
Chert	-	-	-	-	-	-	-	
Gannister or fireclay	-	-	-	-	-	-	-	70
Shale and chert-bands	-	-	-	-	-	-	-	
CROW CHERT and LIMESTONE	-	-	-	-	-	-	-	

The coal under the pebbly grit is visible near Hind Hole Beck, on Raydale side, at Gunnerside Beck Head, and in the gill half a mile north-west of Blakethwaite Smelt Mill. In the first-mentioned place it is 9 inches thick; where exposed in Gunnerside Beck it is 7 or 8 inches thick, but at a point 200 yards south-west of here there is 15 inches of coal resting on another 15 inches of mixed shale, coal, and fireclay. The gannister-seat sometimes changes into grit or flagstone; in Gunnerside Beck and East Gill it is in parts very coarse-grained and contains prominent pebbles of quartz. The two gannisters with an intermediate coal are seen well in the scars on the south side of the east and west gill by the Swinnergill Mines. In Gunnerside Beck, in the Gill about a quarter of a mile north-west of Blakethwaite Smelt Mill, and at Little Punchard Head a bed of hard, compact, grey chert lies on top of the lower gannister or fireclay; perhaps this corresponds to the cherty limestone above the thick gannister of "Crack Band" in Stonesdale. The supposed Fell Top Limestones of Stonesdale seem to be represented eastwards in part by chert. In the east and west gill by the Swinnergill Mines there are on this horizon 2 or 3 feet of limestone and cherty sandstone resting on less cherty flagstones. In the east and west gill south of Lownathwaite Mines a thin band of very compact dark chert full of spiral univalves

crops out ; some 12 feet under this a calcareous sandstone, 2 or 3 feet thick, and occasionally coarse or almost pebbly, appears. In Gunnerside Beck, &c., the Crow Chert and Limestone above the Ten-Fathom Grit readily interchange. This is seen very well on comparing the section in the gill that goes through the second "a" of "Blakethwaite" with that in the sike scarcely a quarter of a mile west by the Lower Blakethwaite dam. The limestone is as a rule of a yellow tint, excessively crinoidal and decomposes readily. It makes an unusually strong show on the dip-slope in Gunnerside Pasture, and seems here almost as pure and grey as the Main Limestone. Near Little Punchard Head it is again fully exposed, and has its usual yellow crinoidal character ; it is nearly 40 feet thick, and has yielded in some parts as much lead-ore as the Main Limestone.

C. T. C.

CHAPTER IX.—CARBONIFEROUS LIMESTONE SERIES

—continued.

DISTRICT 6. ARKENDALE.*

We preface our description of the Yoredale Rocks of Arkendale with a section of the beds from the Millstone Grit down to the Third Set (Three-Yards) Limestone as shown in a shaft.

Section in a Shaft at Fourth Whim, Wet Shaw, Arkendale.

From a copy lent by Dr. Robinson of Richmond.

	Ft.	Ins.
Coal	2	6
MILLSTONE GRIT, a coarse-grained, thick-bedded pebbly grit	86	6
Shale	31	0
Mudstone	3	0
Shale	10	0
Mudstone	4	6
Shale	6	0
Mudstone	4	6
Shale	27	0
Flinty chert	15	0
Shale	3	0
Crow Chert, a siliceous mudstone	8	0
Shale	9	6
Second Crow Chert	13	0
Crow LIMESTONE, a brown calcareous mudstone or impure limestone	12	0
"Soapy grit"	6	0
Coal	2	0
"Soapy grit"	6	0
Shale	9	0
Ten-Fathom Grit	64	0
Shale	17	0
Girdle-beds, thin shaly flags	12	6
Chert or Iron Bed, rusty siliceous mudstone	12	0
"Red Beds"	13	0
Shale	7	0
"Black Beds," generally black siliceous mudstones	14	0
Shale	2	0
Mudstone	5	0
Shale	3	0
Main chert	18	0
MAIN LIMESTONE	72	0
Sandstone	40	6
Shale	15	0
Underset chert	36	0
UNDERSSET LIMESTONE	19	6
Sandstone	36	0
Girdles, generally thin shaly flags	18	0
Sandstone	70	0
Shale	36	0
THIRD SET of limestone (Three-Yards Limestone)	12	0

* The usual abbreviated form of Arkengarthdale.

The Five-Yards Limestone has a fairly clear outcrop in Arkendale. It is first shown by a line of large swallow-holes on top of the east bank opposite Shepherd's Lodge, from which spot it may be followed into the river, where its whole thickness of about 30 feet is exposed. It weathers rather yellow and seems to be impure. The west bank of the river is composed of thick Drift but part of the limestone is seen, dipping east, in Roe Beck, a little above Shepherd's Lodge. Its course is thence obscured by Drift as far as Punchard Gill where a considerable part of the rock again crops out, just below the farmhouse. From this point eastward into the next map it is completely Drift-covered.

Just north of the outcrop of this limestone in Arkle Beck, what looks like the same bed appears in the bank above; it rapidly descends into the bottom of the valley but was not to be found in the stream; it seems far too thick to be the small limestone above the Five-Yards Limestone, and as there is clear evidence of a vein in the foot of the bank between the two outcrops, we infer that the Five-Yards Limestone is here repeated by a fault.

The beds immediately above the last-described are well exposed in Punchard Gill where the following section was measured:—

Punchard Gill.

	Ft.	Ins.
THREE-YARDS LIMESTONE, with grit-top and base	- 10	0
Shale - - - - -	- 10	0
Coal - - - - -	- 0	2
Shale - - - - -	- 5	0
Close-grained sandstone - - - - -	- 25	0
Shaly flags - - - - -	- 15	0
FIVE-YARDS LIMESTONE - - - - -	-	

The Three-Yards Limestone is visible here alone, in this part of Arkendale. Owing to the great mass of Drift at the head of Arkendale the grits and shales above the Three-Yards Limestone (Twenty-seven Fathoms Grit) are rarely exposed. The few isolated exposures in Roe Beck call for no special notice.

On the north side of Dale Head, the Underset Limestone is exposed in the hillside above the first farm. Its outcrop continues quite bare for some distance north-west, and several powerful springs issue from it. Just above the New Bridge it becomes obscured by thick Drift and is more or less conjectural right round the head of the valley, till we reach the high road to Tanhill.

A little south of this, close to a watering-trough, are some shake-holes into the limestone, while a little further on some glassy cherts which rest upon the limestone are exposed. Both the limestone and cherts occur in Roe Beck, and the former is well marked further east by swallow-holes. Routh Quarries are worked in the Underset beds, and show well two faults,

both of which throw down to the south. Punchard Gill gives a fine view of the same rocks, the chert here being a strong bed with hard glassy cores, some 20 feet thick, while the limestone is about 15 feet thick. The limestone is quite bare round Tongue End and may be followed to Little Punchard Gill, south of which a feature alone shows its position. Just beyond the sheepfold this bed rises so rapidly as to suggest a fault; but the Drift renders this point obscure. The cherts come into sight again at Danby Dam and a little further on the limestone crops out and can be followed to Danby Level, and to the edge of the map. The Eight-Fathoms Grits or "deading," which come next above, are not well seen except about Routh; they call for no special notice.

The Main Limestone forms a finely marked feature where it enters this area, about Arkengarthdale Head. The large number of swallow-holes higher up the hill clearly show where the cherts above set on. Close to Raven's Park Farm, a small hollow shows some 5 or 6 feet of chert with about a foot of shale beneath and then the top of the Main Limestone. As the cherts here do not make a strong feature they are most probably split up by shale-partings. To the north-west of the farm the Drift creeps up over the outcrop of this bed, but big swallow-holes frequently give a view of its top, while the base is finely exposed in Roughton Keld, whence a large stream constantly issues, apparently draining the water from the opposite side of the watershed.

For a long way to the north there is no further evidence till we reach the great rushy hollow in which Mud Beck splits up. Here a powerful spring, evidently rising from the Main Limestone, deposits much tufa. Robin Dub, a large round hole, with a similar spring at the bottom, evidently comes off the same rock. The higher reaches of Crook Sike are cut through thick Drift, and it is impossible to say whether this limestone continues right across the watershed to join the outcrop connected with the Greta area or not; in absence of reliable evidence we have ended it off as shown in the map. Passing up the great hollow in Rushy Moor and over the watershed we come upon limestone and chert in the head of Hound Beck, near Sleightholme; from which it is evident that the Main Limestone lies close under the peat all along this valley.

Except for some doubtful swallow-holes there is no evidence of this bed on the west side of Mud Beck or in the great hollow about Beck Crooks, the first clue to its exact position being a swallow-hole in which the Black Cherts appear just above White Springs. A short distance further on the limestone itself is quarried in Swansit Quarry. The whole rock has been opened out here, but in Roe Beck it is obscured by Drift and detritus. In the Deer Holes, a series of large swallow-holes a little to the south-east, in several cases the limestone is exposed with a few feet of the black cherts above it. Similar swallow-holes occur

round Routh Top. After rounding the hill this bed is thrown down some 20 feet by Routh Vein. This may be clearly made out both by old pits and the swallow-holes, some of the latter with chert at the top occurring close to the main bed of limestone. The cherts about here form a small but sharply defined feature immediately above the limestone, and the interruption in this feature clearly marks the position of the fault. A second fault seems to throw down the base of the limestone a few feet, but it does not affect the top sufficiently to be marked at the outcrop. Bare limestone shows at intervals as far as a large quarry on the side of Punchard Gill. Just below this quarry, in the stream, the base rests on grit, while up the beck the junction of the top with the cherts on the north bank is soon reached. A small fault here throws the limestone up some 15 feet, but shortly after the top re-enters the stream, the cherts above it being finely exposed. This unusually clear section yielded the following measurements :—

Punchard Gill.

						Ft.	Ins.
Shale	-	-	-	-	-	35	0
Red Beds	{	Hard cherty bed	-	-	-	5	0
		Cherts and shale	-	-	-	20	0
White crystalline limestone	-	-	-	-	-	5	0
Shales	-	-	-	-	-	15	0
Very hard, almost glassy cherts (main cherts)	-	-	-	-	-	15	0?
Shale-parting	-	-	-	-	-	-	-
MAIN LIMESTONE	-	-	-	-	-	70	0

Between Great and Little Punchard Gills the fault just referred to gives a double outcrop to the Main Limestone. The top seen in the bed of the stream may be followed by means of large swallow-holes round into Little Punchard Gill. Its lower part is cut out by the fault which throws the Main Cherts against the middle of the limestone. Continuing down the hill we come to a second series of swallow-holes, which again show cherts over the limestone and give a second upper boundary. This boundary ends off in both valleys against the fault. The base, seen in Great Punchard Gill may also be followed to the second gill, which shows the limestone lying, on both sides of the stream, on the grits below. This boundary is suddenly cut off by the fault which throws the Underset against this base of the Main Limestone. The latter rock crops out higher up on both banks of the stream and enters its bed just above Punchard Level (better known as Boat Level). Here it forms the sides of a very picturesque gorge; giving in fact a perfect section of its whole thickness. About Low White Hill the top of the Main Limestone is quite clear on the south of the fault; but for a short distance is repeated on the north side. The base-line is not repeated and may be followed from the new level round the front of the hill and above Danby Dam. Just south of this the fault seems to split into two, but the ground is rather

obscure. The upper boundary of the Main Limestone is clearly marked by swallow-holes, which frequently show chert resting on limestone, as in Rowantree Holes. A little further down the hill the south branch of the fault crosses the stream and north of it there seems to be a second top to the limestone; this can be followed into the limestone-quarry close to the kiln. The second branch of the fault has been proved to pass close to this kiln and to throw the top down, probably nearly 20 feet. From this point to the edge of the map the outcrop of the Main Limestone is clear and unbroken.

The strata above the Main Limestone on the north side of Dale Head differ from those seen in the area about Reeth and Danby End. Instead of cherts and shale-partings we have a considerable thickness of grits and shales. The best developed of these at first is the bed known as the "wormy grits," on top of which lies a thin band of limestone better known further north as the Little Limestone. The "wormy grits," so called from their containing vast numbers of fucoid markings, are quarried at Baxton Nab, and can be followed round the foot of Cleasby Hill, forming Brow Edge, and so passing into the bold crag of Bleakhow Edge. The limestone above them, though not visible here, is known to exist from mining evidence in the closely adjoining area. In Long Gutter, one of the branches of Crook Sike, several flaggy grits set in between the "wormy grits" and the Main Limestone, one of them making a strongly marked terrace about Garded Hill.

The Little Limestone and the grit on which it rests form a small scar at the junction of Ease Gill and Frumming Beck. In a gill on the north of the former the Little Limestone, with cherts and shales immediately above it, is again exposed, after which it passes rather obscurely along the hill-top beyond the limits of this Quarter-Sheet. The flaggy grits and shales below the "wormy grits" are well exposed lower down Ease Gill, showing a still greater deviation from the lower Swaledale type. The same beds form the rounded outlier of Coney Seat Hill. After leaving Frumming Beck the "wormy grits" may be fairly well followed by their feature round the west side of a great hollow, till we reach the highest wall of the Beck Crooks Intake. Here they form a small scar in places, and one little stream shows chert and siliceous limestone resting on them; the beds dip sharply towards a fault, which throws them up to the west. They reappear at a pile of stones, whence they are easily followed to Little Red Gill, on the east side of which they form a strong crag. Chert-fragments above the Little Limestone abound here, but the limestone itself is probably dissolved away at the outcrop.

A large fault now throws these beds down into the bed of the stream at Beck Crooks, but for some distance further their outcrop is completely Drift-covered. In Annaside Beck the "wormy grits" are succeeded upwards by impure limestone and dark

chert with shale-partings. The whole sequence of the beds in this stream is given below:—

Annaside Beck.

	Ft.	Ins.
Shaly sandstone - - - - -	15	0
Shale - - - - -	15	0
Shaly chert - - - - -	3	0
Shale - - - - -	8	0
Pink and white limestone and chert - - - - -	5	0
Shaly chert - - - - -	2	0
Impure limestone - - - - -	4	0
Shale - - - - -	5	0
Cherty beds with thin sandstone - - - - -	15	0
Hard cherts - - - - -	10	0
Chert with laminæ of shale - - - - -	1	6
Chert and limestone - - - - -	3	0
" Wormy grits " (part only) - - - - -	15	0

To the east the grits rapidly die out and the Swaledale type of the rocks is resumed.

The Little Limestone round Cleasby Hill is succeeded by a series of cherts and shales, the uppermost part of which forms the Red Beds. Swallow-holes along the top of the Red Beds indicate the presence of limestone; they occur more especially at the northern foot of the hill. The lower cherts and shales crop out at intervals about Green Hill and in the head of Long Gutter, the flaggy cherts of the Red Beds, which are calcareous and fossiliferous here, forming little detached hills, such as Tarnhow Hill, Long Rigg, &c.

In Ease Gill these beds are scarcely recognisable. The following section of them occurs there:—

Ease Gill.

	Ft.	Ins.
Thin flags and shale - - - - -	-	-
Chert, dark and shaly - - - - -	3	0
Shale - - - - -	20	0
Chert - - - - -	6	0
Shale - - - - -	25	0
Chert and limestone (LITTLE LIMESTONE) - - - - -	10	0

In Frumming Beck the highest of these cherts puts on a calcareous aspect and becomes redder, evidently beginning to assume the appearance of the Red Beds to the south and east; while about the horizon of the second are calcareous shales with *Cauda galli*, similar to those seen near Booze in Arkendale.

These beds make a considerable spread about Little Cocker; that hill consisting of very fossiliferous, calcareous, shaly beds, similar to those on Tarnhow Hill, and forming the base of the Red Beds. To the south-west they are cut off by a large fault as shown on the map, and are not met with again till a fine section in Lad Gill (Annaside Head) is reached, where they assume the typical form of the Red Beds, and consist of a

massive red encrinital limestone with cores of pink glassy chert. Below are black cherts and shale, representing the Black Beds, while further up the stream we have the shales and shaly flags at the base of the Ten-Fathom Grit. The Red Beds may now be easily followed eastward to the corner of Leading Stead Hill, where they form a bare surface. Across Roe Beck and on to Routh Top they make a clear feature, while at the latter place they are frequently exposed in the little "hushes" about the small dams. It is noticeable that they become rather shaly here, and contain less limestone than in Lad Gill. At the same time veins in them have yielded less lead-ore. They are now thrown down by Routh Vein and are traceable to Great Punchard Gill by the feature they make, which is not as well marked as usual. In the Gill itself the red limestone and chert does not seem at all well developed. The various "hushes" on the south side of the stream show the shaly cherts, and Little Punchard Gill, where it turns sharply west, exposes the red limestone and chert above the shaly cherts. Round Whaw Edge there are no good sections of the Red Beds, but they have been turned out in several of the pits on the hill close to the east edge of the map.

The Ten-Fathom Grit crops out in the upper part of Cleasby Hill, which is capped by a moderately strong grit, but not, however, the highest bed of the series, which is somewhat of a gannister in appearance.

In Ease Gill the term Ten-Fathom Grit, as so often happens with names of this class, becomes a misnomer, for the series considerably exceeds that thickness, owing to the incoming both of flaggy beds below and of shale-partings in the middle. The section in one part of the stream bank runs as follows:—

The Ten-Fathom Grit, Ease Gill.

							Ft.	Ins.
Shale	-	-	-	-	-	-	20	0
Sandstone	-	-	-	-	-	-	5	0
Shale	-	-	-	-	-	-	2	0
Sandstone	-	-	-	-	-	-	2	0
Shale	-	-	-	-	-	-	10	0
Sandstone	-	-	-	-	-	-	5	0

In Ease Gill the sandstones frequently die out and come on again in wedges, the beds as a whole being more shaly than the typical Ten-Fathom Grit. The strong gannister-like grit at the top of the series becomes much thicker in this area, as may be observed in Dry Gill, where the Crow Limestone rests upon it. It is this grit that further north develops into the "Firestone," and not the whole Ten-Fathom Grit as is often supposed.

The Crow Limestone rests on the top of the Ten-Fathom Grit in the stream just below William Gill Foot, but it is cut out to the north by a rather large fault; to the south it is obscured by Drift, till we reach Annaside Beck, which gives a nearly com-

plete section of these beds. The limestone and grits now make a fairly good feature as far as Lad Gill, which has made a clean cut through the whole of them. As usual there is a considerable bed of shale at the base, while above are shaly flags. Above the shaly flags a short but deep gorge has been cut in the stronger flags of the Ten-Fathom Grit. At the top of the scar bounding the gorge lies a little shale, and then, on the flat above, the gannister, while still further up the stream are the Crow Cherts. To the east of this stream the Ten-Fathom Grit makes a broad spread, but is mostly covered with thick peat; the base, however, is clear enough. Round the head of Roe Beck, by Routh Top and into Great Punchard Gill, the feature of these beds is well marked; and on the north bank of the latter stream the whole series is exposed. On the south side, owing to enormous landslips, the outcrop of these flaggy grits is not so clear, but about the head of Little Punchard Gill the top is well shown by the Crow Limestone, which can be easily traced; the base, both here and round Whaw Edge, makes a fairly bold feature. On Flincher Bottom Moss the Crow Beds again mark the upper boundary, but after passing Luck's All Vein the upper beds are faulted out by Dam Rigg Vein. The peat-road down the hill shows in its bottom and sides the lower flags of the Ten-Fathom Grit and enables us to fix the position of the base.

The Crow Limestone itself has a rather obscure outcrop in the ground south of Ease Gill. It is seen in Frumming Beck, a little above a large sheep-fold, and again in Dry Gill, where it rests on the gannister-like top of the Ten-Fathom Grit. The moor about here is much peat-covered and almost featureless, so that it is impossible to fix the course of the grit accurately. The upper boundary is exposed due north of Cocker Quarry, which shows pretty nearly where the Crow Beds end off against a fault. A second nearly parallel fault terminates their range westwards. Further up Frumming Beck some strong black cherts, belonging to this series, occur. The Top Crow Chert, which has a small bed of limestone (Fell Top Limestone) above it, becomes, in the quarry on Great Cocker, sandy and flaggy, so as almost to pass into a very fine sandstone, but still preserves a cherty nature. To the east the top-cherts are soon cut off by the fault, which separates Great from Little Cocker, but to the west they may be followed for some distance by little swallow-holes in the calcareous bed, the line of swallow-holes falling almost into the line of the fault which bounds the Millstone Grit.

On the south side of this fault the strata rise rapidly to the south, until we reach Mirk Fell End, where they flatten. In consequence these highest calcareous and cherty beds are brought to view in a few places. One of these is marked on the six-inch map at the head of Dry Gill, near Tan Hill, as a "limestone-quarry," and has apparently been also worked to a small extent for road-metal. A great flood that occurred in this district in

December 1882 tore up a huge mass of peat from the little stream, Seavy Sike, close to Tan Hill, and laid bare a perfect pavement of this highest calcareous rock, beautifully polished and striated by glacial action.

Returning to the area near William Gill, we observe that the cherts seen at Great Cocker crop out again in Great Red Gill, and must continue along Mirk Fell Side parallel to William Gill; for the lower Crow Cherts and shales occupy the sides of the stream most of the way, up to a small branch near a coal-level, in which the following section of the Top Chert is met with:—

Great Red Gill.

			Ft.	Ins.
Fell Top LIMESTONE	-	-	-	4 0
Top Crow CHERT, flaggy chert with <i>Productus</i>	-	-	-	5 0
Shale	-	-	-	-

In William Gill itself the upper Crow Beds are obscured by Drift, but about Annaside Head there are several clear and interesting sections:—

Annaside Head.

				Ft.	Ins.
FELL TOP LIMESTONE, thin, resting on	}	-	-	5	0
TOP CROW CHERT, with <i>Productus</i>		-	-	-	-
Shale	-	-	-	5	0
Chert	-	-	-	2	0
Shale	-	-	-	6	0
Coal	-	-	-	4 inches to	1 0

In the next little gill close by the section is as follows:—

Near Annaside Head.

					Ft.	Ins.
FELL TOP LIMESTONE	-	-	-	-	1	10
TOP CROW CHERT	-	-	-	-	6	0
Shale	-	-	-	-	10	0
Coal, 6 inches	}	-	-	-	-	-
Sill, 3 "		-	-	-	0	9
Shale	-	-	-	-	10	0
Thin flags	-	-	-	-	2	0
Shale	-	-	-	-	10	0
Cherts	-	-	-	-	15	0
Shale	-	-	-	-	2	0
CROW CHERT and LIMESTONE	-	-	-	-	15	0
Shale	-	-	-	-	5	0
Gannister, top of the Ten-Fathom Grit	-	-	-	-	-	-

About 200 yards east of this section two bands of limestone suddenly wedge in below the coal, the lower one being 5 feet thick and coarsely encrinital; but this seems quite a local phenomenon.

In Lad Gill most of the cherts reappear, though not the basement-limestone, but at the head of Roe Gill the latter bed

apparently thickens much and has a well-marked outcrop. The lowest cherts and limestone here make a strong feature above the Ten-Fathom Grit, a higher feature being caused by the Top Cherts which are turning to a very hard siliceous, almost glassy rock, a character which they maintain through the rest of their outcrop in the Arkendale Area. A fine section of all these beds in the head of Great Punchard Gill yields the following measurements :—

Great Punchard Gill.

	Ft.	Ins.
Shale	-	-
FELL TOP LIMESTONE; on very hard chert	5	0
Shales with thin bands of dark chert	30	0
Limestone with wedges of chert	15	0
Shale and chert	10	0
CROW LIMESTONE; encrinital	10	0
Ten-Fathom Grit, flaggy grits	-	-

In no other section about this area do the lowest beds of the Crow Series contain so much limestone as here. The three lowest beds form one bold scar on the north side of the stream; to the south enormous landslips, complicated by a fault, render the exact outcrop rather obscure, but the Crow Limestone has been exposed lately in a hand-level by the side of the old coal-road that crosses into Swaledale. The Top Cherts, however, form quite a bold scar to the south of the fault shown on the map, and are remarkable for the vast number of siliceous casts of little *Goniatites* contained in them. These are opal-like in character and give thin fragments of the rock a semi-transparent aspect. The feature made by these cherts may be followed to the "hush" at Little Punchard Head, where they are cut off by Bishop's Vein. To the south they run round into Blakethwaite Gill. There are several exposures of the lower cherts close above the Ten-Fathom Grit in the neighbourhood of Little Punchard Head. About Great Pinseat the Crow Beds frequently come into view; in some quarries close to the peat-road (wrongly marked "limestone-quarries") the cherts above the Crow Limestone are worked for road-metal, and a series of small shafts due north of the western quarry shows this limestone quite clearly. Dam Rigg Vein and Luck's All Vein throw the cherts against the Ten-Fathom Grit, thus cutting out the Crow Limestone, and run on as a master-vein into the adjoining area to the east. About Wetshaw Head on the Arkendale side fragments of the Top Cherts abound, and the beds occur in place in a hand-level close to the moor-wall.

Between the top of the Crow Cherts and the Millstone Grit there intervenes a variable thickness of shale, some 30 feet up in which occurs a carbonaceous band, generally accompanied by an underclay or more frequently a gannister. A second underclay appears above this, but the lower band proved to be the

more constant, and has been of considerable use as a datum-line for estimating the curious changes that take place in the base of the Millstone Grit above. The coal that accompanies this lower gannister was formerly worked further east on Hurst Moor.

The band of gannister occurs in this district about the head of Great Punchard Gill and again at the Head of Roe Beck. Here the basal grit of the Millstone Grit being absent, it makes a sharp feature in the hillside and can be followed for several hundred yards.

In William Gill it crops out at the mouth of the great coal-level, but is quite lost sight of along Mirk Fell Side. Close to the high road, about Great Red Gill, it has once been used for road-metal. Its occurrence here, close to the Little Limestone, marks clearly the position of a large fault.

Further west the gannister and coal just rise above the bed of Mirk Fell Gill some distance above the bridge; the coal is about 6 inches and the gannister 18 inches thick, the latter consisting of an intensely hard white siliceous rock. Close above the gannister lies a thin band of limestone which contains beautiful specimens of *Goniatites*; but unfortunately is broken up into little bits by joints, so that it is quite impossible to extract the fossils whole. These beds, which here appear on the crest of a sharp anticline, are again brought to the surface, higher up the stream, by a fault shown on the map.

G. B.

CHAPTER X.—CARBONIFEROUS LIMESTONE SERIES

—*continued.*

DISTRICT 7.

(1.) BIRKDALE, AND THE UPPER PART OF THE BASIN OF THE SWALE.

The district bordering Mallerstang on the east is called Birkdale. This name is applied to the continuation of the Swale valley above its junction with Great Sleddale.

The lowest beds are found in the north. What these are is clear from the sections in Westmorland, south-east of Kirkby Stephen. A small inlier of the Main Limestone appears in the valley-bottom, north of Uldale Beck.* It is overlain by shale, sandstone, and grit. The sandstone and grit form a dip-slope at Lambs Moss. These beds in their position, as well as in character, correspond to those mapped in the next Quarter-Sheet (102 S.E.) as "the coal-sills." They are here, as there, overlain by the thin Little Limestone, which crops out at the road-side, not quite 400 yards south-east of Uldale Beck foot, at a little gill called Sweet Gill. It is a cherty limestone, and chert occurs at about the same horizon in the main stream a little further south. The limestone is exposed in the next gill to the north (Black Scar Gill) and chert again still further north, beyond which the bed is hidden under peat and detritus.

In Uldale the sandstone and shale over the Main Limestone appear; but the Little Limestone is not visible there, though it is seen not far off along with chert in Lambing Hole gutter. At the wash-fold in Uldale shale comes on above the "coal-sills," and a little higher up a limestone, 1½ feet thick, rests on sandstone.

At a waterfall the shale is overlain by a sandstone, which we identify with the Ten-Fathom Grit. The sandstone is overlain by chert and that by shales. Near the top of the shales there is a thin sandstone with a fossiliferous top and perhaps a second similar bed not far off. At Uldale Force we get a gannister-like grit, with a thin coal in it, resting upon the shales. Immediately above the force there appears to be a fault; for the gannister looks as if it would abut against shales, which are vertical, striking E. 10° N. As we do not again meet with the gannister up stream, the fault must throw the strata down to the west. There is an apparent break in the grits over the vertical shale; but that looks like a downcast east. Conse-

* Not to be confounded with the dale of the same name, which lies on the south-west side of Wild Boar Fell.

quently we believe the big fault, which in Westmorland throws the Main Limestone down west, to bend in such a way as to pass just above Uldale Force. It is not very satisfactory, but such a big fault can hardly die out all at once, and we could see no evidence for any other course for it.

Over the disturbed shales, which are sandy and flaggy in their upper parts, there comes a bed of sandstone and grit, the top of which runs up the hollow to Seavy near to Fell End; at least so we judge by the shape of the ground, for the overlying shales are not actually visible here. Higher up comes the great mass of coarse grit and flagstone which forms Mallerstang Edge.

South-east of Uldale the run of the beds is obscure and puzzling to a degree. The base of the upper grit of Mallerstang Edge is traceable along Lodge Edge nearly to Brockholes, and the underlying shales crop out in several places. In these shales there is certainly one, if not two beds of sandstone, the lowest of which corresponds in position with the bed over the disturbed shale in Uldale. It crops out in the higher parts of Little Lodge Gill, in the grains of Great Lodge Gill, and in Great Doe Sike. At a lower horizon in three of these gills we found sections in grit and sandstone. We did not actually get any shale between this lower grit and the higher sandstone; but there appeared to be some; for the grit could very well be traced into Brockholes Gill, where we did see overlying shale, which looked as if it would run between the two beds.

In Brockholes the base of the grit is flaggy. In position it corresponds apparently with the Mallerstang Flags. The underlying shale is exposed below Brockholes Force. Below the shales we have a bed consisting of pebbly grit, flags, and grit, succeeded downwards by shales. The exact course of the conglomerate north-east from Brockholes Gill is hidden by Drift, except close to the gill; but there can be no doubt that it runs to where a conglomerate appears in Great Doe Sike, which also forms a crag south of that stream. At this crag a fine-grained blocky sandstone lies cheek by jowl with the conglomerate. The shales overlying this blocky sandstone come out in Doe Sike below the exposure of conglomerate. We therefore supposed a north and south fault to run between the conglomerate and the blocky sandstone. But we do not see the conglomerate again north of the section in Doe Sike.

The blocky sandstone, though it cannot be actually traced under the Drift from one spot to the other, is evidently the same as a bed of sandstone and gannister, with a coal in it, seen in Great Lodge Gill. The underlying shale forms an inlier; for owing to a roll of the beds the gannister crops out twice in the gill. Immediately north of these sections in Great Lodge Gill we see in Little Lodge Gill the Ten-Fathom Grit and the overlying chert, and over the chert come shales in which occurs a thin sandstone with a fossiliferous top, precisely as in Uldale.

Therefore we suppose an east and west fault to run between Great and Little Lodge Gills. Over the shale lies a little sandstone, which we take to be the base of the gannister. The gannister is obviously the same bed as that of Uldale Force.

In Brockholes Gill below the blocky sandstone shales and a thin fossiliferous limestone crop out near the foot of Little Doe Sike, the latter answering perfectly to the Fell Top Limestone. Further down stream we come upon the Ten-Fathom Grit, of which we get a fine section at the waterfall and in the gorge below it. There are here two seams of coal in the grit. The underlying shales, which contain two or more thin beds of fossiliferous limestone, appear near the wash-fold.

Between Little and Great Sleddale the run of the beds is obscured by peat and detritus; but most of the small gills give sections. In the branch of Little Sleddale called Coal Gill we have the impure fossiliferous Fell Top Limestone, as in Doe Sike, and above it the strata described later on, p. 141. The next gill which affords sections (Eas Gill) lies about 700 yards east of Little Sleddale. At the foot we have the Ten-Fathom Grit; and above that a good section in shale, which contains several thin impure limestones or "shiver-beds" (cherts). Not far above the highest of these, which is of a better quality than the others, we see a lot of broken gannister lying about; but the solid rock does not appear. Above this spot there is a great deal of shale, over which comes a sandstone; and then shale again and over it grit and sandstone. In Black Scar Gill little is to be seen, and in Crew Gill only lumpy plate and shale.

Though the ground, described above, on the west side of Birkdale is rather obscure, yet the section in the main streams itself is clear enough. We will briefly point out the beds met with in descending the stream from the inlier of Main Limestone mentioned above (p. 127). At the ford near Uldale Foot a bed of sandstone of the "Coal-sills" is seen: while shale and sandstone of this series forms Black Scars. We come upon the overlying chert (Little Limestone) at a foot-bridge 500 yards below the ford. The Ten-Fathom grit crops out in the stream below Birkdale Cross; and below Crook Seat we come to the underlying shales with thin limestones. Here the beds seem to be thrown down east by a fault, for we next get in the river the calcareous beds that lie above the Ten-Fathom Grit. This rock forms the bed of the river as far as Ellers, where the overlying chert comes down to the stream. The grit has a coal in it, which is visible 200 yards below Ellers Bridge. The top of the rock is generally formed of gannister immediately overlain by chert or limestone. The grit itself is generally flaggy and consequently its base is often rather indefinite. There is a curious section at the top of the grit just above the first waterfall below Little Sleddale. The top bed consists of fossiliferous sandstone with *Crinida galli* on a plant-bed. This is like the usual form of top; but here the fossiliferous bed is apparently unconformable over sandstone and shale. Probably this is due to the underlying sandstone being extremely false-bedded.

Just below Birkdale Farm we noticed a curious block of green sandstone full of chert-pebbles. Unluckily it was not in place; but probably it had not come far. There is also a singular top to the Ten-Fathom Grit in Whitsun Dale. The top is there formed of a peculiar-looking green rock, six inches thick, lying on sandstone with *Cauda galli*, which rests on fossiliferous sandstone. This is so like the top in Birkdale that we cannot help thinking that the block of green sandstone with chert-pebbles comes from the same horizon.

The obscurity of the ground on the west side of Birkdale is caused quite as much by the fact of the beds dipping in the same direction as the slope of the ground, and by the presence of great masses of Drift, as by the faults which exist. All these causes of obscurity being absent on the east side, that quarter is much clearer. The beds come into view in several of the gills descending from Coldbergh Edge; and as they are all alike, it will be enough to give a general section.

At the bottom we have the inferior of Main Limestone mentioned above (p. 127); and over this shale and sandstone capped by chert and the Little Limestone. Over the limestone come shales with a fossiliferous sandstone or a sandstone with a calcareous top; then come more shales, and then a bed of flaggy sandstone, the Ten-Fathom Grit, on which lies a bed of chert; over the chert come shales, in which there are two thin beds of fossiliferous limestone (the Fell Top Limestone). Over the shales comes a bed of gannister or gannister-like sandstone, and over the gannister a thick bed of shale, above which we have the grits of Coldbergh Edge. The beds below these grits can be traced by means of frequent sections all down Birkdale to Swaledale proper, that is to the junction with Great Sleddale. The most southern complete section is at Ellers Brow south of Birkdale Farm. In the river we have the Ten-Fathom Grit overlain by chert, above which come shales. The two Fell Top Limestones, very thin, crop out close together above Ellers, and at the waterfall the gannister (here very thin) forms Ellers Brow. Shale lies over the gannister, and above the road we come to the base of the grit-outlier shown on the map. A little further east, over Birkdale Farm, a sandstone equivalent to the gannister is seen, and the underlying shale at the farm, below which comes the chert at the Ten-Fathom Grit. We do not see the gannister again going east nor the Fell Top Limestones, so that they cannot be traced into Whitsun Dale.

Following the beds into Westmorland we detect the two fossiliferous Fell Top Limestones and the overlying gannister in several of the gills, and can by this means trace them as far as Standards Mire.

The evidence for the fault which breaks the beds at Bastifell and north of Nine Standards is conclusive in Westmorland: for the Main Limestone and associated beds are thrown up to the north; so that the flags at Bastifell correspond to the Ten-Fathom Grit. Like it they are overlain by chert and shales, in which occur two thin seams of fossiliferous limestone overlain

by a bed of gannister-like sandstone, precisely as in all the sections in Birkdale. The gannister makes a fine escarpment at Fox Crag, and abuts against the high Millstone Grit of Nine Standards. The same bed forms Winton Force, below which one of the Fell Top Limestones occurs. It crosses the watershed and County-Boundary about the head of West End gutter and plunges down against the fault, which is seen in the stream at the head of Whitsun Dale.

Eastwards the fault is visible in the bed of Backstone * Beck. It throws gannister, dipping sharply south, against flags and shales well up in the Millstone Grit, a shift of considerably over 200 ft. There it splits into two; a northern branch passes through Backstone Castle, and throws Yoredale shales (close under the Millstone Grit) against the gannister, which is here finely developed; while a southern branch, crossing Near Grains, is well seen in the sides of a little gorge. Between the two branches lie Yoredale rocks, while south of the southern branch the Millstone Grit extends some hundred yards eastwards, thus clearly marking the line of fracture in spite of the covering of Drift. This southern branch dwindles away to a mere hitch of 2 or 3 feet in the foot of Little Bitch Gill.

The gannister, which forms Backstone Castle, also crops out east of the little slack which runs thence northward. It forms several fine crags known as the Hawthorn Crags and has thin seams of coal associated with it. The rock is compact and hard and the top is beautifully polished. That there are no scratches seen is probably due to the fact that the other rocks were so much softer as to be incapable of scratching it.

Near Hawthorn Crags.

	Ft.	Inch.
Gannister, variable	5	0
Coal		2
Shale	6	0
Coal-smut		1
Grit and flags, very variable	3	0
Coal-smut		1

From this point southward the rock rapidly thins, for the following section was proved in a small adit-level:—

Little Bitch Gill.

	Ft.	Inch.
Sandstone full of carbonaceous plant-casts	1	0
Carbonaceous shale	3	0
Laminated siliceous bed	2	0
Hard impure coal	1	6
Dark shale		

From this point the dip takes these beds below the stream-level; but a roll quickly brings them up again, and the gannister reappears in Foxhole Gill. For some distance to the south the ground is obscured by great landslips and when seen again the only representative of the gannister is three feet of fireclay.

* This should be Bakstone or Bakestone.—J. R. D.

Turning round into the next valley we find the gannister exposed in the numerous gills on both sides of the main stream, being in all cases a flaggy siliceous rock accompanied by a few inches of coal. A particularly good exposure of it occurs at the foot of the great waterfall north of Raven Seat. The shale between it and the overlying pebbly grit is here 150 feet thick, while at Punchard Head, about six miles to the east, it is only 50 feet, and the intervening sections show a steady decrease of thickness to the east.

At the south end of the hill above Raven Seat the gannister is seen in Caveside Gill. Three veins and a smash and a fault cross this gill; and the gannister seems to be thrown down on the north; but the section is not quite clear. On the south and east of the gill the gannister is very hard and strong, and forms a sharply defined feature known as Crack Band. Higher up the gill, near the smash, a coal six inches thick underlies a gannister six inches thick.

The base of the Ten-Fathom Grit and the underlying cherty beds crop out in Whitsundale Beck just below Oven Mouth, three quarters of a mile below Raven Seat. At this spot, which is at the foot of Caveside Gill, the grit is crossed by a calcareous vein, which may also be a fault, trending N. 35° E. Perhaps this vein is connected with those seen in Caveside Gill. From Oven Mouth the grit is in force along the stream up to Raven Seat. The rock consists of ripple-marked flags, false-bedded in places, and somewhat massive; and forms at Boggle Hole a fine gorge, the cliffy side of which is in places coated with calcareous tufa. This is rather singular, as the overlying beds contain but little lime.

Just below Raven Seat a shale is interbedded not far from the top of the sandstone; and at the bottom of this shale-band there is a fossiliferous bed on the top of the main mass of sandstone. Perhaps this fossiliferous band should have been taken as the top of the Ten-Fathom Grit, but the overlying sandstone is not easily separated southward from the main mass. Above Raven Seat the sandstone over the shale-band comes to the stream, its base forming the High Force; and near the wash-fold above High Force the overlying fossiliferous beds come on. These appear also in the main stream half a mile west of Raven Seat.

Higher up Whitsun Dale, and a little below the foot of Little Cogill, there is a thin seam six inches thick (belonging to the fossiliferous bands, Crow Beds), of a peculiar green colour, resting on sandstone with *Cauda galli*. A similar seam occurs at about the same horizon in Westmorland below Nine Standards, and probably also in Birkdale (p. 130).

The highest of the cherty bands that occur in this part of the series rises from Whitsundale Beck at the foot of Long Gill and can be followed on the east bank as far as the next gill, beyond which the ground is obscured by landslips as far as Blae Gill, where the upper chert has a clear outcrop. On both sides of Bottom Beck, exposures of one or more of the cherts are numerous in the little side gills; and in one of them, Lodge

Gill, flattened specimens of *Goniatites* and *Orthoceras* are fairly plentiful. At the south end of the hill above Raven Seat, Caveside Gill affords a complete section of these beds at this horizon:—

Caveside Gill.

							Ft.	Ins.
Gannister	-	-	-	-	-	-	2	6
Coal	-	-	-	-	-	-		6
Shale	-	-	-	-	-	-	30	0
Chert	-	-	-	-	-	-	1	0
Shale	-	-	-	-	-	-	20	0
Chert	-	-	-	-	-	-	3	0
Shale	-	-	-	-	-	-	30	0
Chert	-	-	-	-	-	-	1	6
Shale	-	-	-	-	-	-		
Ten-Fathom Grit	-	-	-	-	-	-		

(2.) WINTON AND KABER FELLS.

There is a good deal of obscurity about the Yoredale beds on these fells. Immediately east of the Bastifell fault there is a pretty clear section. South of the word "Crag" in "Greenfell Crag" there are sandstones with a coal forming Scurrath Edge; and over them we get the cherty Underset and the Main Limestones, followed upwards by calcareous shales and the grits of Peatpot Hill. These are evidently the "coal-sills" without the coals. Over these we find shales with chert, and over the shales flags forming Bastifell, which correspond to the Ten-Fathom Grit. On the flags come thin limestone, chert, and shale; and still higher up cherty limestone not far below the gannister-like sandstone of Fox Crag (p. 134).

The Main Limestone appears close to the fault and can be traced eastward for half a mile to the head of Seavy Sike. Here a fault which is seen in the Gruntley Beck seems to pitch up the beds on the north-east side, so that the Main Limestone forms the prominent green hill called High Dolphinseat, below which we have chert and limestone, presumably the Underset. This limestone, though it cannot be traced the whole way owing to Drift, is running to unite with the Underset in Howgill Sike. But the Main Limestone of High Dolphinseat instead of following the run of the Underset seems to be cut off by a fault along its northern face, up-casting on that side; for the slope of the hill known as Kaber Rigg is formed by a sandstone and two strong limestones dipping north or north-east at a greater angle than the slope of the ground. These two limestones are obviously the Main and Underset; and are striking eastward for Stowgill, where there is a clean-cut section, showing both of those rocks and their basement-sandstones with a thin limestone between them, such as is not unusual. Westward the Underset Limestone, which forms the green band known as Low Dolphinseat must be thrown down to the outcrop already mentioned. The Main Limestone can be traced on pretty fairly considering the Drift, to unite with the outcrop above Howgill. In the gill we see below it two beds of limestone, namely, the Underset and the intermediate bed, very cherty, as in Stowgill.

East of Stowgill the Main Limestone lies in the form of a broken anticline. Over it we have good sections of the upper beds in all the gills descending into the Belah from Winton and Kaber Fells, the general ascending section being shiver-beds and shale, grits and sandstones ("coal-sills"), on the top of which is the thin but pure Little Limestone. This is exposed in Bleaberry Beck, especially near Slapewath Force. Over it come fossiliferous shiver-beds, and a set of sandstones and shales, the Ten-Fathom Grit, well seen about Bleaberry Force; on it we have a thin limestone and chert, above which come shales; and over the shales more sandstones with shale-partings and cherty limestone at the top, above which come the shales with the two thin fossiliferous Fell Top Limestones underlying the strong gannister-like sandstone of Winton Force. The gannister appears not only in Fox Craggs and at Winton Force, but also under Brownber Edge, where it has a coal on or near its top. It is overlain by a considerable thickness of shale. But though the general succession is clear enough, the details are uncertain; for the various sandstones are all much alike, and between the Main Limestone and the gannister there is no well-marked bed that can be followed far; and the gannister itself becomes poor eastward. On the east side of Middle Gill it seems to be thrown down eastward by a fault; for a rock like it, and having a little limestone below it, occurs at a lower level in the next gill (Deep Gill) than can be accounted for by dip. This rock is a double sandstone with a coal at the base of the upper bed. We cannot trace the gannister further east: but it crops out with its coal in Little Wygill just below the road leading to the Kettlepot Colliery, underlain by the two Fell Top Limestones.

In Deep Gill there is a considerable thickness of shale over the representative of the gannister; and near the top of the shale a thin sandstone and coal. The coal was formerly extensively worked at the Kettlepot Colliery, and by means of the old adit-levels can be followed into Yorkshire. Over it we have a thin shale and then a sandstone, which can be traced round to unite with the Millstone Grit of West Stonesdale. The sandstone is overlain in Back Gutter by iron shale with fireclay. The shale passes up into flaggy sandstone; but the base of the latter, owing to the great amount of peat covering the hill, is not clear.

In Great Wygill and Reagill two thin fossiliferous limestones answer to the Fell Top Limestones, and over them lie two thin beds of sandstone, above which comes the Tanhill coal-sill and coal: over the coal there is flaggy shale, and lastly the flags of Taylor Rigg. The geology here is somewhat obscure. The shale below the flags crops out again in Ease Gill at from 20 to 30 chains from the County-Boundary; and then we have cherty beds in the stream striking along it; so that it looks as if we had crossed a fault throwing up lower beds on the east side. A north-westerly fault with such a throw breaks the beds of Grey Grits, which may be the fault in question. But between Ease Gill and Grey Grits comes an important east and west fault described

above (p. 123) in Arkendale, the evidence for the course of which westward we will now give.

At the north edge of the map we have the following beds which have been traced southward from excellent sections on Stainmore (in the adjoining Quarter-sheet, 102 S.E.): these are the Main Limestone which occurs west of the high road leading from Arkendale to Barras in Westmorland; above it the coal-sills very strong, with the road running upon them; east of the road the Little Limestone, pure and encrinital in places, makes a good feature; over it, though not well seen, come shales, and finally the outlier of strong sandstone forming the hill called High Grey Grits. Now in Potter Sike, where we should expect to find the Main Limestone, we have instead cherty shale, such as occurs above the Little Limestone; and below these we have a thin limestone, precisely like the Little Limestone, resting on grits like the coal-sills; and below the grits a thick limestone crops out, which cannot well be anything else but the Main Limestone; and below it in due order the Underset. Thus it is clear that immediately south of Grey Grits and north of Potter Sike there must be a fault throwing the strata down on the south-west side. This fault is clearly shown in the next map (102 S.E.) by the repetition of the limestones.

It will be seen by the map that the direction of the fault in Yorkshire is more east and west than the one described above in Westmorland: but it would seem as if the latter were only a branch of the former, which may go straight on, throwing out successive branches to the N.W.; for there are several nearly parallel faults in Westmorland running north-westwards on the north side of the east and west fault. The most eastern of these shifts the Grey Grits, and in the next map is clearly proved by the repetition of the Little Limestone of Plat. Then comes the fault just described as throwing down the Main Limestone of Green Rigg to Ewebank: a third, more doubtful, breaks the Main Limestone on Ewebank: a fourth ranges along the Belah valley from Woofers Moor, where it cuts off the Little Limestone, to High Ewebank, with a great downthrow on the south-west side; for the Main Limestone appears again on that side, cropping out below High Ewebank, and overlain by shale and strong grits with a little limestone, which do very well for the coal-sills. These are best seen on the south side of the Belah, where they are thrown along with the Main Limestone and shifted west by a prolongation of the east and west fault; so that the Main Limestone is thrown westward from Cowan Edge to the outcrop (mentioned above, p. 133) in Stowgill. The faults on Kabers Rigg and Dolphinseat have the same general direction as the faults mentioned above. The consequence is that the Main Limestone is broken no less than eight times between Bastifell and Grey Grits. It may then be well understood that there is much uncertainty about the precise positions of the many similar sandstones that occur in the measures over the Main Limestone.

CHAPTER XI.—CARBONIFEROUS ROCKS—*continued.*

MILLSTONE GRIT.

(1.) Baugh Fell.

This hill is capped by a little over 500 feet of Millstone Grit. The series here consists to an unusually large extent of soft flags and shales. On the south and south-east sides of the hill we have an equivalent of the Ingleborough Grit in a coarse pebbly sandstone, well developed in Swarth Gill and Rackenthwaite Gill, and thence eastwards as far as Long Gill. But here the grit becomes flaggy, and in Rawthey Gill and northwards gets so soft and thin as to be recognisable only by its relative position to the "grindstone" below. Around the north and north-west sides of the hill flags, apparently on the same horizon, overlie dark shale and form a distinct feature, which, however, in the south-west side loses itself under piles of sandstone-blocks and shale, that have slipped from above.

A descending section in Swarth Gill shows thick sandstone with thin bands of shale, passing down into grit with a few scattered quartz-pebbles, the presumed Ingleborough Grit. This grit rests on sandstone, in part resembling gannister, which is underlain by shale with thin bands of sandstone. Where well developed the pebbly grit has a kind of gannister on the top of it; this forms the sill of the coal-seam that has been so extensively mined at Tanhill. The coal itself occurs, as a "smut" only, in Rackenthwaite Gill (the next gill east to Swarth Gill), but a little further east has been mined by a considerable number of drifts, shown on the map as the Baugh Fell Coal Pits. The gannister crops out in Grinning Gill, and fragments of coal indicate the presence of the seam also, though peat conceals its actual outcrop. East of this gill we have no clear indications of its existence. The Tanhill Coal is succeeded by a great thickness of shales and flags with here and there lenticular wedges of grit; the only noticeable point in them being the presence in the upper part of Swarth Gill of some calcareous bands occupying approximately the same horizon as those shown under Water Crag Hill some 15 miles to the north-east (p. 158).

About 360 feet above the pebbly grit above mentioned a second coarse and massive rock forms the brow of the hill, and 150 feet higher up a third coarse pebbly grit forms a small escarpment, followed by a gentle slope, in which black shale crops out. The second of the three pebbly grits runs round the southern side of Baugh Fell and extends northwards to West

Baugh Fell Farm in a nearly level plateau. Some flaggy sandstones overlying it were formerly worked for paving-stones and flags in the Baugh Fell Quarry. The uppermost of the three grits forms the higher plateau known as East Baugh Fell. Lastly the highest point of the hill, 2,216 feet above sea-level, is occupied by a small outlier of flaggy sandstone, the geological position of which may be best indicated by stating, that if the hill had been 50 feet higher, the horizon of the Trilobite Limestone (p. 145) of Great Shunner Fell would have been reached. The uppermost of the three grits consists in its upper part of an intensely hard gannister, full of casts of roots and stems of plants.

Flaggy sandstones and shales crop out in streamlets of West Baugh Fell, between the two lower grits. One of the sandstones yields excellent flags and has been quarried for this purpose.

A fault crossing the summit of Baugh Fell in a north-easterly direction, is shown by an abrupt fall to the west of the two upper strong grits. Near East Tarns it has the effect of causing a kind of step in the grit-surface of the hill-top, the edge of the step being within 2 or 3 feet of the fault, and finely ice-polished. This effect of the fault is noticeable from a distance and makes its position unmistakable. It is evidently dying away in the north face of the hill, for it shifts the upper grit a few feet only and does not appear to cut the lower one at all.

A. S., G. B.

(2.) Swarth Fell.

The base of the Millstone Grit of Swarth Fell is not well shown. The line taken is 140 or 150 feet above the top of the Ten-Fathom Grit. There is little bare rock seen along this line, but at the head of the Sike that runs past Round Ing some loose blocks of pebbly grit occur which seem nearly in place; and there are also various blocks of gannister belonging perhaps to a bed immediately below the pebbly grit. Half a mile or so north of this place there is no pebbly grit seen at the base, but only some rather strong flagstones resting on shale. The grit at the north end makes a good feature for some distance south.

On the west side two beds of sandstone are seen in the beck running down from the col between Swarth Fell and Wild Boar Fell, and probably represent the Coal-Sills. A coal has been worked lower down the stream, and an impure cherty limestone is also visible.

R. H. T.

(3.) Wild Boar Fell.

In our description of the Yoredale Rocks of this neighbourhood (p. 90) we referred to a gannister-like sandstone or quartzite. About 100 feet above this rock comes the lowest of the Wild Boar Fell Grits, forming a cliff known as White Walls. This

grit is double, that is, it consists of two distinct beds parted by a band of shale of no great thickness. There is a coal-seam on the top of the lower grit. These two grits form the upper part of the scar called Scridbles; and, though much obscured by slips and masses of detritus in Yoadcomb, can be traced to Low White Scar at the south-east end of the fell. Here they bend round Aisgill Head, and form the flat between Wild Boar and Swarth Fells. The lower part of the rock forms Standard Brow, below which the underlying shales are seen. Thence northward round the west side of Wild Boar Fell the position of the base is somewhat uncertain, as the rocks are hidden by thick peat. But near the head of Forceps Sike a bed of gannister crops out, which is probably near the top of the rock. Over the White Walls Grit comes a thick shale, nearly in the middle of which is a thin, but persistent bed of calcareous sandstone. At or near the top of the shale is a seam of coal. Over the shale comes the grit which forms the top of Wild Boar Fell, a plateau of a mile in length from north-east to south-west, girdled by precipices along its eastern face, known as Black Bed, Yoadcomb, and High White Scars. At the southern end of the last the base of the grit bends round to form the Band, encircling the corry at Aisgill Head, and, though the precipices cease, yet the outcrop of the bed is clearly marked by the steep face of the Band, and a similar escarpment along the west face of the fell to the north-east point known as the Nab. A fault, which is a continuation of a copper-vein, with a downcast on the north-west side, is visible near the Nab, and two small parallel faults throw the strata down north in Yoadcomb Scar.

J. R. D.

(4.) Little Fell.

Immediately north of the fault at High Dolphinsty the highest beds seen are micaceous sandstone and shale, forming the ridge as far as Low Dolphinsty. Beneath the shale is a hard sandstone or grit, the top of which crosses the ridge at Low Dolphinsty. Its base is marked by a spring on the eastward slope, and runs round the promontory called Little Fell so as to form an outlier, the western outcrop being fairly well marked by the shape of the ground. A little way below it another bed of grit also forms a scar, but does not appear in Long Gill on the west side, its place being hidden by peat. Beneath it we have black shales, well exposed in Collier Gutter. In these shales there is a thin seam of fossiliferous sandstone and some chert. The beds roll about a great deal; and at the place where we see the chert a fault, running north-west, crosses the gill. This fault can be traced by means of the swallow-holes in the Main Limestone of Scandal Beck heading for Dolphinsty. The two grits forming Little Fell are without any

doubt the two beds of White Walls. They are best seen at Middleark Scar, which gives the following section:—

Middleark Scar, Little Fell.

					Ft.	Ins.
Grit (top not seen)	-	-	-	-	-	-
Black shale	-	-	-	-	20	0
Gannister, with irregular base	-	-	-	-	2	0
Soft-sandy grit	-	-	-	-	7	0
Harder grit (base not seen)	-	-	-	-	-	-

J. R. D.

(5.) Mallerstang Edge and the neighbouring part of Birkdale.

Before describing in detail the grits forming the rugged crags of Mallerstang Edge we will give the general section and the correlation established by comparison of these grits with those of Wild Boar Fell, Shunner Fell, and elsewhere.

The highest rock seen on the top of the Fell at High Seat is a sandstone with a thin limestone at its base. A little lower there is another sandstone which is in places of a gannister-like character. Below the gannister come greenish grits and shales, and then a strong gannister-like grit, and probably more shale. The shales are bluish and irony, and contain a thin fossiliferous limestone with crinoids, *Spirifer*, and *Productus*. Below the shales comes a group of several grits with shale partings and coals. These form Mallerstang Edge, High Band, High Loven Scar, Hanging Stone Scar, and Brant Crag. The lowest part of this group is equivalent to the grit of the Nab, Black Bed Yoadcomb, and High White Crags, and the Band, on Wild Boar Fell, and to the grit of Swarth Fell and Swarth Fell Pike in Westmorland; and to the grit of Knoutberry Currack, Brian Grain Edge, Shunner Fell Rake, Pickersett Edge, and Hearne Edge on Great Shunner Fell; and also to the grits of Jinglemea and Broadmea Crags in Cotterdale, and probably to the grit of Long Crags under Sails. We consider this rock as equivalent also to the grit of Water Crag and Rogan's Seat. This group of grits we call B on the general table, p. 146.

Below it comes a thick shale, and then a thin but persistent bed of calcareous sandstone (C), precisely as on Wild Boar Fell. This forms the Low Band on Mallerstang. It is often flaggy.

Below the underlying shale we have group (D) of grits. This consists of two beds close together, often forming two scars. There is a coal on the top of the lower bed. This group, which forms Low Loven Scar is the same as the lowest grits on Mallerstang Fell End. It is obviously the equivalent of the grits of White Walls and Low White Scar on Wild Boar Fell, and of the grits forming Coldbergh Edge.

Owing to the obscurity of the ground between the Ure and Mallerstang Edge, we cannot directly make out the relation of the group of grits (D) and the grits of Howgate Edge and Ingleborough. There can, however, be little doubt that D corresponds to the beds D¹ and D² (in whole or in part) of the Shunner Fell sections, which lie above the horizon of the Howgate Edge grit.

Below the group D on Wild Boar Fell there is (as stated above) a quartzite or gannister-like grit. This is probably identical with the similar grit of Lambfold, which itself is probably the equivalent of the lower part of the Howgate Edge or Ingleborough grit.

We will now give some details about the Mallerstang beds. Immediately north of the Sleddale and Dolphinsty fault we have in Red Gill an outcrop of group C as a faulted inlier containing *Cauda galli*. At the foot of Slate Gutter there is a good section of the shale just below group B. In these shales there is a thin sandstone not far below B. The base of B runs south-east from Red Gill to Brant Crag and thence to an exposure of massive grit in Little Grain. The fault probably runs just south of the Crag, but it is not actually seen. A bed of grit occurs in the stream 200 yards below group B. This we suppose to be on the south side of the fault.

Close to the fault on the west side of the Red Gill a bed of flaggy grit occurs which is rather puzzling. It contains numerous casts of *Spirifer* and *Productus*. From its position it would seem to be a part of B; but we do not know of any other place where B is fossiliferous. Perhaps there may be a branch fault down north on the north side of the fossiliferous band, which would then be the calcareous grit of group C.

In Red Gill 300 yards above the base of B we come to a section in shale, above which is a grit with *Stigmara* and a gannister top. This bed forms a wide-spreading dip-slope to the north; but south of the gill can only be traced a short way. It either dies out or coalesces with the grit of Brant Crag; for the first grit seen above that crag is on a still higher horizon.

On the horizon of the latter grit, due west of Hugh Seat, there is a curious bed consisting of a mass of rounded and broken quartz-crystals. Above it there comes a thick bed of shale, with a grit over it, probably as an outlier, on the slope of Hugh Seat. In the shale at the head of Red Gill there is a seam of coal; and on the top of the grit forming High Loven Scar there is also a coal.

The fault which breaks the Main Limestone at Wether Hill is clearly to be traced through the grits of Mallerstang by a great gash in the escarpment and by the shifting of the beds down north. Its extension into Yorkshire is very uncertain; but it probably is a continuation of the Stockdale Vein. North of the fault group B consists of five beds. The principal escarpment,

known as High Band, is formed of three grits on the top of which there is a coal and underclay. Above the coal lie two beds of grit, the lower of which can be traced. Over these grits comes a thick shale, above which are the grits and limestone of High Seat. A small fault, down on the south-west side, crosses the County-Boundary at High Seat. Evidence of this fault is got on the Yorkshire side in spar and slickensides at the head of Brockholes Gill.

A bed of gannister also on the south side of the gill abuts against shale. A fault on the same random is seen in Westmorland, but with an opposite downthrow. At 200 yards north of High Seat a fault crosses with a downcast to the north-east, the principal evidence for which is in Westmorland; but signs of it were also seen in Yorkshire in the grains of Brockholes Gill.

A third fault of more importance, with an upcast on the north-east side, crosses the County-Boundary 450 yards north of the previous fault. This fault is seen in Westmorland not far from the boundary. In Yorkshire it seems to split into two. One branch bending south crosses Brockholes Gill at the foot of the grains, where it brings shale on the west against the underlying coarse grit on the east; the other branch going straight on crosses the gill at Brockholes. We could not trace any of these faults far south of Brockholes Gill, for the ground between that gill and Great Sleddale is very obscure; the features are poor and the ground much cumbered with detritus.

In Coal Gill, a branch of Little Sleddale, we have above the Fell Top Limestone (p. 129) a carbonaceous sandstone with gannister and coal. This obviously is the equivalent of the blocky sandstone and gannister of Uldale and Doe Sike. The coal and gannister probably have shale over them, but this cannot actually be seen. A little higher up conglomerate and white pebbly grit appear in both branches of Coal Gill; and in Great Coal Gill a coal a little above the conglomerate, and still higher a great series of flags a good deal disturbed.

At the north end of Mallerstang Edge, called Fells End, two of the beds of grit have been much quarried for flags and ashlar. There are four beds of grit here beneath High Pike. The lowest is hardly recognizable, being covered with *débris*, but its existence is well known from its having a coal-seam in connection with it, which has been worked, and it forms a conspicuous feature further south.

Two levels enter the hill lower down and east of the quarry-tips. A lower level runs up from Blue Gill on the Yorkshire side and communicates with the others by shaft. The coal is said to be 4 feet thick, of which 1 foot in the middle is only good for limeburning, and to lie on a grit which was not visible here. From the coal to the top of High Pike it would seem that the four beds here with the interlying shales make a thickness of over 300 feet. This is not the top in this district, for below High Seat and west of it another sandstone with interven-

ing shales comes on, giving another 100 feet, and further beds taking us to the top of the hill make a total of about 700 feet.

The Fells End coal-seam appears to be continuous, or at any rate visible at intervals, to the colliery at Outhgill. On the way the grit which forms its "seat" grows in thickness and importance and forms a well-marked scar. Half way between Fells End and Blea Combe Scar the coal is exposed, and there it is only 30 inches thick, with shale-partings.

Beds 2 and 3 of these grits, counting from the base, are both flaggy in character, and No. 3 contains in some places bullions of calliard, which no doubt would deteriorate it as a flag-rock. This is the case about Trough Riggs, near the Colliery. No. 4 is much coarser and generally a conglomerate. A coal-smut occurs on the top of it just above the Blea Combe fault, south of High Brae.

These crags run along with rugged parallelism and form a picturesque bit of scenery, enhanced by the talus of huge fallen blocks on the slopes beneath. With regard to this one striking feature is observable in several places. The talus often does not make a slope creeping up to the base of the rock from which it is derived but forms a raised ridge at a little distance with a hollow between. At first this was not easy to explain, for the ridge of rubbish forms an obvious trap for any falling fragments. It seems probable though that in the winter when most of these blocks are falling the hollow between is filled up with unmelted snow, over which the fragments slide until their progress is arrested by preceding fragments at the lower edge of the snow, or if their impetus is too great they may of course bound on beyond, still leaving the hollow side of the ridge unfilled save by snow. This explanation seems plausible, but has not been verified by personal observation in the winter.

The upper part of the series, above the five grits already mentioned, is covered with rainwash and peat; it probably consists mostly of shale, but at the top two grits are seen with one little yellow and ochreous limestone, full of the stems of crinoids, between them.

J. R. D., R. H. T.

(6.) Abbotside Common and Shunner Fell.

The first important feature above the Main Limestone is that formed by the coarse grit of Long Scar and Howgate Edge over the Buttertubs pass between Swaledale and Wensleydale. This rock is of a marked lithological character, and forms so prominent a feature that it can be traced over the whole extent of the southern part of the map and identified from step to step in various localities. It thus forms as a whole a fixed datum-line. The beds immediately above it can only be identified by a careful comparison of adjacent sections.

But above these more obscure beds we have another fixed line, namely, that given by the outcrop of the rock forming

Pickersett Edge. This rock can be clearly traced all round Great Shunner Fell, of which it forms the basis. Its base is marked by the nearly unbroken features known as Brian Grain Edge, Shunner Fell Rakes, Pickersett Edge, Jinglemea, and Broadmea Craggs. Its extreme north-western point is marked by Knoutberry Currack.

In the grains at the head of Grainy Gill we find pebbly gannister-like grit about 25 feet above the Ten-Fathom Grit and about 25 feet higher a thick bed of coarse grit (p. 101). Above the coarse grit we have shales with gannister and coal; and then a sandstone, which is not well seen, but which seems to correspond with the grit of Whetstone Rigg. Tracing these beds round the hill we find the pebbly gannister thickening out to form Howgate Edge, while the overlying coarse grit with its coal forms a higher feature, the top of which runs by an adit-level to the coal, which was once got here, and above the coal-level comes Hood Rigg formed by the rock of Whetstone Rigg. The grit on Howgate Edge and its correlation with the Ingleborough Grit has been already mentioned (p. 101).

It has a thin shale-band and a coal-seam in it near its base. Its top is gannister, above which there is a coal, 1 foot thick. The base of the next grit, namely, that which lies below the workable coal mentioned above, is a little below the next waterfall in Fossdale. This bed is also a pebbly grit. Above it we have shale and sandstone; and over the shale the base of the Hood Rigg grit is found at the next waterfall, on the 1,850 feet contour. The grit cannot be traced continuously further westward.

In Hearne Beck the grits of Howgate Edge are very poor. The upper bed seems to have thinned away entirely; and the lower one is only represented by rather coarse yellow flags, below which occur black shales and fine-grained false-bedded sandstone, forming a waterfall, which probably correspond to the Ten-Fathom Grit.

The Howgate Edge or Ingleborough Grits form a bold promontory between Hearne Beck and Cotterdale, called Humesett. The rock is a massive, pebbly, felspathic grit in two divisions, formed by an interbed of shale containing a coal-seam. The top of the upper division consists of gannister, a little above which is a coal-seam.

The beds deteriorate rapidly north-westward, for in the next gill beyond the Cotterdale Coal-pit, Long Gill, the grit of Humesett Crag has dwindled to a thin sandstone; and the upper member is represented by a calliard-like sandstone. The beds above this are not well seen, but appear to be principally shale. Two beds of sandstone occur in the shale, one near the top and the other near its base, not far above the calliard-like top of the Ingleborough grit. In East Gill the Ingleborough grit consists of two beds of pebbly grit; and in the overlying

shale a bed of sandstone occupies a similar position to that mentioned as occurring in Long Gill.

At the horizon of the Ingleborough grit in West Gill we have at the base a massive sandstone at Coal Force. This bed thins south, as in the two next gills it is 8 and 4 feet thick. There is a coal below it. Over the sandstone comes a thin bed of shale and then pebbly grit in two beds. All these beds, namely, pebbly grit, basal sandstone, and Crow Limestone can be traced south as far as How Mea gill, beyond which everything is obscure.

Sections now become abnormal and puzzling. In Scars Gill above the Ten-Fathom Grit we have a thick and massive bed of hard gannister-like sandstone, which forms Lambfold and Cross Gill Crag. Over the gannister there comes a shale and then a pebbly grit with a thin coal. The grit itself is only 4 feet thick. The gannister is probably an abnormal development of the hard sandstone of Coal Force in West Gill, and perhaps represents the lower of the two Humesett grits. The little pebbly grit seems to be all that remains of the upper part of the Ingleborough grit. Over it we have a considerable thickness of shale, and then sandstone and shale with a coal.

Northward the gannister becomes obscure, while the thin pebbly grit is replaced by a false-bedded calliard-like sandstone. This bed crops out in the two next gills and becomes, as we go north, partly a compact sandstone and partly a coarse grit. Over this there comes in Washer Gill a thick bed of shale and then a coarse felspathic grit and gannister lying unconformably on the shale in a very marked way. This bed we were not able to trace.

The Ingleborough coarse grit cannot be traced north of the Ure head-water, where it forms Hellgill Crag. The gannister which forms the base of the Ingleborough grit cannot be traced satisfactorily north of Washer Gill. In Birks Gill thin calliard occupies about the same horizon: this bed was, however, not seen in the Ure; but a sandstone occurs there rather lower down which may be the equivalent of the gannister, but the ground between the two is too much Drift-covered to allow of the beds being traced. It seems probable, however, from sections in and near Stockdale and from general considerations that the gannister in question is the gannister of Uldale Force (p. 127) and that it is the equivalent of the grit of Howgate Edge.

North of the head-water of the Ure thick masses of Drift conceal the rocks: but the beds seem to rise in that direction, so that we hypothetically take the base of the upper Ingleborough grit to where a grit is seen on the County-Boundary, and in Hell Gill, but everything is very uncertain. In Hell Gill the beds run against the Sleddale fault, the further evidence for which we give in our description of the Mallerstang district.

Following Scars Gill upstream to a bend where it has eaten into the south bank, we find the following interesting section:—

Scars Gill, Lunds.

						Ft.	Ins.
Black shale	-	-	-	-	-	20	0
Pebbly grit	-	-	-	-	-	6	0
Shale	-	-	-	-	-	14	0
Grit	-	-	-	-	-	2	0 (+)

The last-named bed is the upper portion of the Lambfold grit, which is thus seen to be overlain by a second bed of pebbly grit separated by shale; the upper pebbly grit, however, appears to be inconstant and to wedge out horizontally.* In the overlying shales occur two thin coal-seams, the lower being about 9 inches, the upper about 7 inches in thickness.

Overlying the beds just traced we have a thick mass of shale, in the lower part of which there are several beds of sandstone; but on the Wensleydale side of Shunner Fell none of these are well enough marked to allow of their being traced far. In the north-west part of the district we have been able to trace two of these beds for about a mile. The lowest of them is a flag-stone, which is seen in Jingling Sike, the head-water of the Ure, and in Washer Gill. It seems to coalesce northward with a lower bed of grit. The next bed is pebbly as well as flaggy. Over it there comes a thick bed of pure shale. These shales appear in all the gills descending from Great Shunner Fell, and in such of those on Sails as give any section at all. Over this shale comes the well-marked grit of Pickersett Edge. This grit consists of several beds of sandstone separated by shale. The lowest bed, which forms the edges mentioned above, is generally a flag-stone, as may be seen at Hearne Head. Here we find the upper part of the rock to be a coarse grit, with a gannister-top. But these characters are not constant. The westward extension of the bed towards Knoutberry Currack seems to consist entirely of coarse felspathic grit. In drawing the top of this bed round Great Shunner Fell we have been guided partly by sections and partly by the shape of the ground.

The overlying bed is a very thick shale, which forms the greater part of Shunner Fell. In it there are two thin bands of fossiliferous limestone, which are to be seen near Shunner Fell Well on the west side of the hill. In one of these Mr. Goodchild found a trilobite. (*See also* p. 160.) A tiny outlier of grit forms the extreme top of Great Shunner Fell.

Sails is another outlier of the same beds as those which form Shunner Fell. The Pickersett Grit is represented by two massive beds of grit, the lower of which is pebbly. Over these comes a thick bed of shale, in which a thin calcareous band was seen in one spot near the head of Jingling Sike. The brow of the hill is formed by a bed of grit over the shale, and the top by sandstone. On the north side of Shunner Fell we have numerous sections similar to those on the south side, and here, too, we naturally find the sandstone-beds between the horizons of the Howgate and Pickersett Edge Grits to become stronger and more definite eastward.

J. R. D., C. E. R.

* It is uncertain which of these two grits is the representative of the Ingleborough Grit.—J. R. D.

Comparative View of the Millstone Grit and the higher Yoredale Rocks exposed under Shunner Fell.

A.—Grit of Shunner Fell Top. Thick shale, with thin fossiliferous limestones.

<i>Stackers Gill.</i>	<i>Daddy Maa Gill.</i>	<i>Brian Grain.</i>	<i>Great Sike.</i>	<i>Stock Dale.</i>	<i>Grainy Gill.</i>	<i>Fossdale.</i>	<i>Hearne Beck.</i>
B. Grit of Knott- berry Curraek. Sandstone.	Grit of Curraek. Shale.	Grit of Brian Grain Edge.	Grit at the head of the sike.	Grit of Shunner Fell Rake. Shale. Sandstone. Shale.		Grit of Pickersett Edge. Shale. Sandstone. Shale.	Grit of Hearne Edge. Flaggy shale.
C. Sandstone of graining.	Shale and limestone at top of scar. Grit at the word "Daddy."	Grit above house.		Sandstone of Whet- stone and Hood Rigg. Shale.		{ Gannister. Grit, base at the waterfall. Shale. Sandstone.	Thin grit. Shale and a yellow limestone. Shale.
Shale.	Shale.	Shale.	Shale.		Shale with sand- stone and grit (<i>Stigmaria</i>). Coarse grit.	Shale. Grit.	Flaggy shale. ? Sandstone, top at the fold.
D. { Flaggy. Coarse grit.	Flaggy. Coarse grit at the word "Edge."	Coal and sandstone below the hut.	Flags at the scar. ? Grit. Shale. Coal and sill. Shale. Gannister.	Probably forms a feature south of Stockdale.			
E. Shale. (the Ingleborough Grit).				Coarse grit with <i>Stigmaria</i> .	Thin sandstone, thickening east and south into coarse grit, and forming Howgate Edge and Long Scar.	Gannister, on pebbly grit, on very thin shale.	Humesett grits, the lower bed.
Calcareous seat- stone. Thin shale.	Shale.	Grow Limestone and calcareous conglom- erate.	Shale.	Shale. Conglomerate, with calcareous top and fossils. Sea-clay.	Grow Limestone.		
		Seat Sandstone with <i>Canda galli</i> and plants.		Shale. Sandstone with <i>Canda galli</i> .	Sandstone <i>Canda galli</i> . Limestone. Shale.	Calcareous bed.	
Ten fathom Grit (flags). Shale. Limestone with fossils. Shale. Main Limestone.	Flaggy. Shale.	Flaggy. Shale. Limestone. Shale.	Flaggy. Shale. Limestone. Shale.	Flags. Cherty calcareous plate. Black shale. Main Limestone.	Sandstone, below Howgate Edge.	Flaggy sandstone.	

(7.) Muker Common.

On Muker Common the base of the lowest pebbly grit runs at an elevation of between 1,500 and 1,860 feet, and shows no sharp changes of level, excepting here and there where it is thrown by faults, among the chief of which we may mention the Muker Side vein and the Lover Gill vein. The first of these throws the base of the Millstone Grit down on the east side nearly to a level with the top of the Main Limestone on the west side: the second vein has a large downthrow westwards.

Coming on above the lowest feature of the grit we have usually another, or in some places, two others, composed of grit of much the same massive pebbly character. The stream-section in Lover Gill shows the parting between the two features seen there to consist of a thin smut resting on a few feet of fire-clay and clayey flags.

Above these pebbly grits we have a coal resting on a fireclay or gannister. This no doubt represents the coal known further north as the Tanhill seam. A section in the west bank of Lover Gill shows the seam in two portions, as below:—

The Tanhill Coal in Lover Gill.

							Ft.	Ins.
COAL	-	-	-	-	-	-	1	3
Gannister, &c.	-	-	-	-	-	-	1	6
COAL, mixed with shale	-	-	-	-	-	-		10

Thirty yards on the east side of the sike another section shows the parting considerably thicker, thus:—

							Ft.	Ins.
COAL, thick	-	-	-	-	-	-		
Shale	-	-	-	-	-	-	8	0
COAL	-	-	-	-	-	-		8

On Muker Edge the seam has been worked in a sike at the head of Greenseat Beck, and a little way on the north-west side of here, and in another sike a little west of the Grains.

In the head of the sike that runs into Cliff Beck by the second "f" of "Cliff" the beds that come on over the seam consist in the main of alternations of shale and flaggy sandstone. Two of the flagstone-bands contain carbonaceous streaks and plant-remains and make small features under the peat.

The pebbly grit at Stags Fell is separated by shales into two distinct beds, the outcrops of which form two picturesque and well-marked escarpments of weathered jointed crags. The entire series from the base of the lower to the top of the upper bed attains a thickness of about 80 feet. On Bleak Haw about 45 feet of shales intervene between the top of the Ten-Fathom Grit and the base of the pebbly grit; following the latter northwards to Turned Hill, we see it gradually overlap the shales, until it rests directly on the Ten-Fathom Grit. The whole of these beds are cut off on Willy Road End, and thrown down westward,

by the Lover Gill fault. The fault from this point, as far south as Thurly Gill, was formerly worked for lead-ore and blende. The refuse-heap from the air-shaft near Willy Road End contains numerous fragments of the Ten-Fathom Grit.

The moors between Oxnop Gill and Lovely Seat consist chiefly of shales, which affording a retentive subsoil have allowed the growth of extensive peat-bogs over them, such as the Giles Great Stones Hags, Ruth Bog, White Beacon Hags, Cogill Head Hags, and Quarry Hags. The pebbly grit circles round the Cogill valley, forming an imposing escarpment at Black Bank, especially between the Shooting Box and Black Bank Top, at the latter of which places it splits up into two beds. Between Quarry Hags and Annasett Rigg a good bed of flags was formerly extensively quarried; it crops out in Cogill Seave Bead; above it lie the following beds:—

Lovely Seat.

							Ft.	Ins.
Grit, rather pebbly, to the top of Lovely Seat (2,213 feet)	-	-	-	-	-	- about	75	0
Shale	-	-	-	-	-	"	10	0
Grit	-	-	-	-	-	"	15	0
Shale	-	-	-	-	-	"	55	0
Flags	-	-	-	-	-	"	18	0
Dark shale, with calcareous concretions	-	-	-	-	-	"	100	0

The outlier of Oxnop Common or Blackstone consists of a basement-bed of pebbly grit, passing in its upper part occasionally into gannister; above this lies a thick bed of black and grey shale with a coal-seam, which was formerly worked, and is stated to be 10 to 14 inches thick. This shale is overlain by a compact fine-grained grit, which forms the summit of Blackstone. A small outlier of pebbly Millstone Grit, known as Red Braes, has been faulted down on the eastern slope of the fell, and another measuring 160 yards from north to south by 60 in breadth lies on its south side.

C. E. R., C. T. C.

(8.) Beldon and Crackpot Moor.

The Millstone Grit, which occupies the Fleak and Beldon Bottom, has already been referred to (p. 99); it reaches no great thickness.

The outlier which forms Crackpot Moor consists throughout of coarse and somewhat felspathic pebbly grit. It forms two features on the hill: the lower one is the natural base of the outlier; the higher one is seen most distinctly 30 or 40 yards north of the Ordnance Station 1,772. It would seem as if the parting between the two divisions cannot at most be more than a few feet thick. There are quarries in the outlier, both near the north-western and north-eastern portions. For an account of the interesting chert-mass on the top *see* pp. 190, 191.

C. T. C.

(9.) Nine Standards and Coldbergh Edge.

In the hillside below Coldbergh Edge we find in ascending order the Ten-Fathom Grit, on which lies a bed of chert, and then shales with the Fell Top Limestones (p. 130).

Over the shales comes a bed of gannister or gannister-like sandstone, then a thick bed of shale, on which lie the grits of Coldbergh Edge.

The lowest bed of Coldbergh Edge is a thin grit, 8 to 10 feet thick, on which is a coal. Over the coal comes a bed of shale, and then flaggy grit, the principal rock of the Edge. This rock in reality consists of several beds of grit, some of which are coarse, and flags and gannister with shale-partings. The base of the whole series is well marked all along Coldbergh Edge from the County-Boundary to the head of Mould Gill, where the underlying shale is well exposed. East of the gill the exact position of the base is not quite clear. It is apparently faulted down on the east side. The underlying shale, however, is seen in Little Cogill, and over it there is a particularly clear section of coarse felspathic false-bedded grit. The base appears again, probably faulted up, in Great Cogill; and again in Cray Gill where the rock is exactly like that in Little Cogill. But north of Davy Mea Well a considerable thickness of local Till obscures the ground, and the manner in which the bed ends off against the fault there shown is problematical.

Though the grit of Coldbergh Edge can be well traced, its base-line is broken in several places by small faults or slips. The rock itself varies in character, consisting of irregular masses of coarse grit and gannister, apparently deposited in the form of banks nearly surrounded by shale. The top is therefore a merely general line. The grit (generally coarse) can be traced as far as Bastifell, where it is cut off by a fault and brought against a bed of flagstone that occurs lower in the series. The overlying shales are exposed in several places and at the very heads of the gills a band of flags over the shale. This band of flags is succeeded by a steep bank, probably occupied by the shale which appears immediately south of Nine Standards Rigg, in the gill called Near Grains. The highest shales seen are encrinital and are therefore considered to be the same as those exposed in Lad Gill (p. 156). The shale is succeeded by the rock which forms the Rigg. The lower part consists of flagstone, which has been quarried, and the upper of coarse grit.

About two miles south-east of Coldbergh Edge an outlier of Millstone Grit forms that part of Abbotside Common called Tarn Moss, in which lies Birkdale Tarn. The northern boundary is quite hidden by peat; but the southern is clear enough from Crook Seat on the west to Hill Top on the east. The most complete section is got east-south-east of the tarn, where we have in descending order gnarled grit, flags, shale with coal, coarse grit on sandy shale. The flags have been extensively quarried at the Hill Top quarry.

(10.) Ravenseat Moor.

In the outlier between West Stonesdale and Whitsun Dale the base of the Millstone Grit varies much. About Kettlepot and Brownber Edge the typical basement-bed is entirely absent and the Tanhill Coal has been adopted as the base-line. But at the high end of the deep scar in Thomas Gill, West Stonesdale, just where the coal ceases to be workable, a thin pebbly gannister sets on. The Tanhill Coal in the gill rests on this bed, which further south, while retaining its gannister-top, develops downwards into the coarse grit exposed in the scar about the head of Potshaw Gill. Still further south another change occurs, and the coarse grit either passes into, or is replaced by finely laminated soft sandstone, which passes insensibly into the shales beneath. This flaggy basement-bed continues all along the hillside above Raven Seat, the little gills, such as Caveside, Intake and Lodge Gills, affording clear sections of it. In the last-named the flags are clearly dying away again, for the coarse grit rests on a small thickness of them, while a little further north the coarse pebbly grit rests immediately on the shales of the Yoredale Series. This last relation is well shown in Graining Scar, about a mile north of Raven Seat, where the base of the Millstone Grit is thrown down abruptly several hundred feet.

It is noticeable, too, that the upper part of this basement-grit is hard and polished, and so full of rootlets, as to lead us to suppose that the Tanhill Coal rests immediately upon it. Following this grit southward, along the west side of the valley, such proves to be the case, for the fragments of coal may be followed from the head of Blea Gill for about a quarter of a mile to the north-west on the top of Low Whitsundale Edge. The grit below slowly thickens till Little Bitch Gill is reached, where it attains its maximum development and is a coarse crumbly felspathic grit with numerous small pebbles. Once more it is gradually replaced by the fine flags and before turning round towards Kettlepot there is very little of the grit left.

It may be seen from the above that where the sections are good the Tanhill Coal is rarely, if ever, absent altogether; but it has been successfully mined quite at the north-east end only of the outlier, in the area marked on the One-Inch Map as Kettlepot Colliery. There it was in former days extensively worked and can consequently be easily followed from the County-Boundary to the head of Deep Gill. According to an old miner the seam was 18 inches thick. In one of the grains of Deep Gill there is no sandstone or "seat" of any kind connected with the coal, the basement-grit being entirely absent, and in another there is only a very thin bed of sandstone.

The flaggy grits above the Tanhill Coal, which are so well developed about Tanhill, make a bold scarp round Kettlepot Side as far as the most southerly coal-workings. South of the faults they occasionally occur in massive wedges, such as form the sharply marked hill of Robert's Seat. Close to the great fault

above Raven Seat, they terrace both sides of the valley, and have been quarried just below Alderson Seat, where they show the usual coarse-grained flaggy character. Further north they seem to be lost in the general slope of the hill, which must here contain an unusually large proportion of grit.

On Alderson Seat we have a much higher bed of strong grit, but as it has no distinguishing features it is not possible to say certainly whether it is below or above the "Fossil Grit." Most probably it is below. It is interesting on account of the fine examples which it presents of *roches moutonnées*. The ice-sheet evidently came from the west-south-west and rode right over this hill.

The highest rocks, of which the horizon can be exactly fixed, occur between the two faults north of Raven Seat. Standing at the base of the waterfall we see the valley suddenly blocked by a huge wall of flaggy grits and shales. The highest grits are fossiliferous and contain casts of encrinites in abundance; towards the top they are shaly and occasionally show the markings known as *Cauda galli*. These clearly correspond to the "Fossil-Grit" seen at the foot of Water Crag (pp. 156, 157). The beds above and below them form bare scars, of which the following is an approximate section:—

Waterfall north of Raven Seat.

		Fr.	Ins.
Gannister-grit, with rootlets	} Grits of Water Crag and Baugh Fell Top	20	0
Hard coal		2	4
Shale and coal		2	0
Coarse grit		20	0
Shale		30	0
Small gannister		3	0
Shale		20	0
Fossiliferous flags	} "Fossil Grit"	20	0
Shale		20	0
Sandstone, rather fine		5	0
Shale		25	0
Shales and flags		35	0
Grit		30	0
Flags and grits, top of the Tanhill Flags, to base of the great fall.			

On the north side of the second fault the beds are thrown up, and a little calcareous nodular bed which lies some way below the "Fossil-Grit," appears in the stream. A rapid rise in the beds to the north soon brings out the great mass of coarse flags which form the great spread towards the County-Boundary. At East Gill Head, two miles east of the waterfall, we find an almost identical section.

G. B.

(11.) Water Crag, Rogan's Seat, and Tan Hill.

This area is nearly confined to the fell-tops and therefore contains but few good stream-sections. It is too, for the most

part, overspread by a thick covering of peat, which increases the difficulty of tracing out small details. The sandstones or grits are often extremely false-bedded and liable to very sudden variations in thickness and occurrence. Still they may be said to usually form four chief beds, the united thickness of which, however, falls short of that of the shaly portion of the series. The lowest grit is usually a coarse massive rock with many pebbles of quartz and felspar. The felspar is generally in a decomposing kaolinised condition, but occasionally still hard and with cleavage-faces visible. The rock is often soft and crumbly even to the fingers, owing perhaps to the rapid decomposition of the felspathic constituents, and the scars weather in somewhat rounded pillowy blocks. This character is common to the same grit in other parts of this district. At its maximum development this lowest grit probably reaches nearly 100 feet in thickness, but in such cases it is usually divisible into two parts by a thin shale and coal-parting. This is well seen in the clear section of the base of the Millstone Grit about Great Punchard Head.

Great Punchard Head.

						Ft.	Ins.
Tanhill Coal	-	-	-	-	-	2	0
Coarse pebbly grit	-	-	-	-	-	5	0
Fireclay and coal-smut	-	-	-	-	-	6	0
Coarse pebbly grit	-	-	-	-	-	20	0
Yoredale Rocks	-	-	-	-	-		

To the north these grits rapidly die out and appear in the fine escarpment facing Bowes Moor only as little wedges of a flaggy nature, but to the south and overlooking Swaledale they continue to form a sharply marked feature, for some distance. A similar thin coaly parting occurs in Hind Hole Beck, where it gives the grit on the south-east side of the beck a double feature. The basement-grit is clearly shown in Gunnerside Beck Head, to the south side of the Blakethwaite vein, both in the stream and the scars. But it changes in development frequently and suddenly, and in some cases becomes so thin, as scarcely to make a feature. This is the case on the fellside south of Hall Moor and east of Hind Hole, though in Hind Hole itself, only a quarter of a mile away, it is very thick. On the above fellside it appears *in situ*, or nearly so, in various places, but with a thickness of not much over 12 feet. In the west bank of East Gill the thickness is 10 or 12 feet. This thickness it keeps for some distance to the south-west, but it is no longer always coarse-grained and pebbly throughout, as it also contains bands of fine-grained hard sandstone and shale.

On the south-east side of Black Moor it suddenly gets thicker (perhaps in the first instance by the incoming of a lower bed of grit), and forms a strong scar of pebbly grit, one of the blocks in which measures 10 feet in length. At the south end of

Black Moor and for a quarter of a mile to the north-east it continues to make a great show and then suddenly thins northwards. In the slip-head, north-west of Black Moor, there is nothing found to represent it below the fireclay, some 5 feet thick, which underlies the Tanhill Coal. At the head of the sike by Low Brown Hill this fireclay contains a good many quartz-pebbles, but there is still no true grit seen below it.

The pebbly grit must, however, be in place close by for there are a good number of blocks of it on the north side of a landslip at the gill-head, and a still larger slipped mass 110 yards to the south-east. In a runner 80 yards south-east of the quarries between Lad Gill and Low Brown Hill the grit is seen in place, with its usual pebbly character, but it makes no feature and is probably very thin. There is clearly no pebbly grit above the great Low Level, but a few yards further north a thin though sharply-defined gannister-bed sets on. Like the normal pebbly grit it is full of pebbles, but the matrix is extremely hard and compact. A small outlier of this rock occurs at Drovers Hole where the County-Boundary crosses the high road, but nothing more is seen of it in the many clear sections to the east of Tanhill excepting a small wedge in William Gill.

Tanhill Coal.

Lying close above and sometimes directly on the pebbly or basal grit is usually a seam of coal, known as the Tanhill Coal. About Tanhill its outcrop is clearly shown by the numerous levels and pits driven in it. About Mirk Fell Head it comes into sight in numerous small sikes, its outcrop being repeated in one place by a small fault. On the face and flanks of Mirk Fell several trials and two small shafts show that the seam has degenerated to little more than a smut. A very sharp roll over of the beds, to the north of the high road, brings on the coal again in Mirk Fell Gill, on both banks of which it appears some 200 yards below the Bridge. It has never been tried in this area, indeed its rapid northerly dip renders the working of it impossible without much pumping, even supposing the seam to be of good quality. Returning to the east side of Mirk Fell some pits put down recently showed only a smut of coal. Some distance to the south in a small branch of William Gill, a level driven on the outcrop of the coal, proves it to range from $1\frac{1}{2}$ feet to sometimes as much as 4 feet, but the average is about 2 feet. In William Gill and on the east side frequent sections in little runners show that the coal rapidly deteriorates in a northerly direction. A shaft between Great and Little Scolit reached it at a depth of 68 feet, but it was too thin to work, and at Annaside Head a level was driven into the outcrop, but the seam proved to be of no value. All along the face of the scarp looking into Arkendale, sections of the seam are frequent, and as we approach Punchard Head we find the seam splitting into three parts, the section at Roe Beck Head being as below :—

Roe Beck Head.

						Ft.	Ins.
Tanhill Coal	{	Coal	-	-	-	2	0
		Shale	-	-	-	6	0
		Coal	-	-	-		2
		Shale	-	-	-	5	0
		Coal smut	-	-	-		3

The coal seems to be impure here, but a little further south from a considerable number of old pits some good coal was obtained. The level at Punchard Head also shows the seam in three parts, each of which may be seen in the stream. A little south of this a large fault throws up the seam and there is no trace of it for some distance. Three borings were put down towards the higher part of Great Punchard Head, but in none of them does the coal seem to be of any value.

Proceeding in a southerly direction from Tanhill into Stonesdale, where the coal has been extensively worked, we find the seam resting on a thin bed of pebbly gannister, which has a clear outcrop between Tan Gill and Mould Gill (north of Lad Gill). Further south the gannister is often replaced by a soft underclay, and the exact position is not so clear. As we approach Lad Gill the seam appears to thin away, for a small level, driven in the bank just above the stream, showed it to be much split up, and quite useless.

Further south at Mould Gill Head we see 8 inches of coal but not the top. About a quarter of a mile south-south-east of here it is about 2 feet thick but much mixed with shale. On the west side of East Gill it crops out in two places. A section in the long sike south-east of Hind Hole Beck shows 14 inches of coal, mixed with shale, resting on fireclay; but the top is not seen.

At Gunnerside Beck Head it was formerly worked, to a small extent, by shafts and levels on both sides of the Blakethwaite vein; but its thickness does not seem to be now known.

It may be inferred from the above facts that the workable coal is restricted to a small area bounded to the north by a line drawn through Tan Hill through William Gill Level. A parallel line drawn from Lad Gill in Stonesdale to the head of Gunnerside Beck seems to indicate roughly its southern limit. To the east about Punchard Head it is very uncertain, parts being fairly good and then turning worthless within a few yards. Doubtless there would be some poor coal within the area here indicated, but there seems to be none of any value outside it. The William Gill Level could proceed no further owing to water, so that there must still be a large area of probably good coal in the neighbourhood of Water Crag which may be some day reached by a rise from the great Gunnerside Level, that is if it should ever be thought worth the expense. The small patch of coal in the Bowes Royalty, known as the King's Pit, has been practically worked out, but there is a deal of coal to be won yet from the great level in Stonesdale.

The coal itself varies much in quality, but it always contains a considerable amount of ash. That won from the William Gill pit burns with an intense white heat, indeed few coals give out so much, but as it is very "small" and will not coke, it requires care in burning. About Tan Hill some of the coal easily cokes and is then a fairly good fuel, but not so hot as that of William Gill.

It is difficult now to realise what an important seam this once was, but when it is stated that people came with carts for coal from Appleby, Penrith, Kirkby Stephen, Bowes, and Hawes, we understand why there are so many old shafts sunk to this seam. A curious illustration of the great age of some of these workings was given some short time back when the workmen, in "holing" into some old levels, found a pick cut out of wood, the points only being tipped with iron; a relic evidently of the days when iron was a scarce commodity.

Overlying the Tanhill coal and separated from it by a varying thickness of shales there is usually a thick bed of flaggy grits sometimes coarse sometimes finer. These form the most massive rocks in the district and make a fine show close to the little inn. Their massive nature is doubtless partly due to false-bedded wedges, but the coarse flags have the look also of having been cemented together by a deposit of silica. Very fine examples of ice-rounding are to be seen in them at Tan Hill.

Along the northern scarp-face, overlooking Bowes Moor, the coarse flaggy character is maintained, and many openings have been made for road-metal. A worse material could not well be found, for it crushes to powder within a few weeks of being laid down.

About William Gill Head the beds are finer, almost sandy shales, but there is little true shale here. The old coal-road along Annaside Edge is made on typical coarse flags, which here form a bold feature. At Great Punchard Head again the whole series is finer in grain, as the stream-section clearly shows. A boring was put down here just about the 2,000-foot contour and passed through the following beds:—

Boring for the Tanhill Coal, at Great Punchard Head.

						Ft.	Ins.
Peat and soil	-	-	-	-	-	10	0
Brown metal (shale)	-	-	-	-	-	22	0
Grey metal	-	-	-	-	-	16	0
Grey post (sandstone)	-	-	-	-	-	26	0
Grey metal	-	-	-	-	-	28	0
Post	-	-	-	-	-	30	0
Dark metal	-	-	-	-	-	19	0
Grey metal	-	-	-	-	-	32	0
Post	-	-	-	-	-	8	0
Tanhill Coal (shale and coal)	-	-	-	-	-	2	0
						<hr/> 193	<hr/> 0

This shows the shaly nature of the greater part of the series for a distance of nearly 200 feet above the Tanhill Coal; but at

the same time it should be said that part of the metal is very sandy, perhaps strictly shaly flags.

Going in a southerly direction from Tan Hill down Stonesdale the old dale-road passes for a considerable distance along the flaggy grits, numerous small openings being also made here for road-metal. In Lad Gill Quarry three-quarters of a mile north-east of Stonesdale Bridge, and in Frith Quarry further south, good typical sections occur. On either side of East Gill they make a fine show, great landslips often occurring at their junction with the more shaly beds below. In some places there are between the third and basement-grits two separate sandstone features, the rocks forming which may vary in character considerably. Sometimes we have excessively even bedded fine-grained flags, as at the south forking at East Gill Head, but more usually coarse-grained submassive flags. In Hind Hole Beck the upper bed makes a strong feature and contains some fairly large quartz-pebbles; the lower bed, consisting of fine-grained flags mixed with shale, makes no distinct feature. Round the head of Gunnerside Beck the second grit has a strongly marked outcrop, but on the west side it is mostly covered with peat.

In Lad Gill, West Stonesdale, there is an unusually fine section of the Millstone Grit series. Some distance above the first great scars of grit lies a succession of grits and shales, above which, just where Seavy Sike (the first branch-gill) joins Lad Gill, is a small coal-seam some 4 inches thick, which may be followed in the banks of the stream for some distance down. Then, still ascending, we come to more flags and shales, till we reach the next branch of the gill. Here a calcareous nodular bed crops out and may be traced some distance. In clear sections it can generally be recognised, and therefore forms a useful horizon. For example, when the beds roll sharply over to the north on Bowes Moor, this same calcareous bed is seen at the junction of Mirk Fell Gill and the next gill west, and serves to show how rapidly the beds fall over to the great fault.

Above the calcareous band there lie some 50 feet of dark shales, crowded in places with fragments of a small-stemmed encrinite. These shales form quite a characteristic feature of the bed of the gill for a great distance east, for the beds rise at about the same rate as the stream. Above the shales, but much obscured here by peat, comes the "Fossil-Grit," forming with the underlying shales an undoubtedly marine group. In a sike on the east side of the head of Gunnerside Beck, there is a sandstone with casts of fossils seen a little way below the feature taken for the "Fossil-Grit." This grit usually consists of rubbly flags of somewhat coarse grain and marked with numerous small spots of ochre. Casts of *Spirifers*, *Crinoids*, &c. are very frequent, and occasionally the original calcite is still observable. Small carbonaceous streaks and plant-remains also occur. There is a good section of it on the east side of Rogan's Seat near the 2,000-foot contour, also in the feature below the

Long Rigg (East Stonesdale), and again at Great Punchard Head, a little below the 2,000-foot contour. At East Gill Head it consists of a soft calcareous sandstone, underlying flags, and contains flags only rarely. The base of the "Fossil-Grit" at Punchard is about 50 feet above the borehole mentioned on p. 155, so that we can tell the exact thickness of the beds between the Tanhill Coal and this grit; it is in fact very nearly 250 feet. The "Fossil Grit" really consists of two beds here, the lower one only yielding fossils so far as we could see. Both features are continued along the front of the great hill facing Bowes Moor, but just under Water Crag they combine, perhaps through the shale-parting dying away, and we have the whole marine group in one sharply defined hill; at the base of which, some 250 yards south of William Gill Colliery, runs the little calcareous nodular bed. Further west the whole group is obscured by a great sheet of peat, here of unusual thickness.

In the shale above the "Fossil-Grit" by the Long Rigg, about a third of a mile slightly south of east of East Gill Head, a thin sandstone-band runs like an intrusive dyke, with shale on either hand. Its sides do not appear to be faults. Perhaps it represents a contemporaneous hollow that was subsequently filled with sand.

In East Gill, above East Gill Head, a blocky gannister with shale above and below it, but no coal with it, comes on some way above the "Fossil-Grit." This same gannister appears also south of Lad Gill (Stonesdale), where its very clear outcrop serves to mark sharply the position of a fault. Both branches of the Water Crag fault are equally well shown by this same bed at the head of Great Punchard Gill.

The highest grit is generally a thick massive rock, often with big pebbles of quartz. It differs from the lowest grit in being harder or less crumbly, owing perhaps to the comparative rarity of felspar. There is a good section of it in the stream above East Gill Head. Here it is compound; the bottom part is rather flaggy below and contains carbonaceous streaks, but upwards gets massive and pebbly, and contains casts of large trees. The middle part is a thin shale with a coal-seam about a foot thick; the upper part is a strong gannister, full of rootlets and occasionally of small pebbles. This soft band in the grit causes it to weather in two features, and the lower one often stretches a long way beyond the upper. This is seen at East Gill Head, where the lower grit extends half a mile west of the upper. The outlier on which the Ordnance Mark 1855 is placed consists of the lower bed only. Both grits are extremely well shown in Water Crag, the gannister being hard and full of rootlets, the lower forming a long line of massive blocks. A double feature runs round the top of Rogan's Seat also. To the north-east at the head of Gunnerside Beck there is a good section in the part of the stream called the Straits; the upper part is here fine-grained, false-bedded, and flaggy; below this comes a false-bedded pebbly portion lying on a coal a few inches thick, and below

this again a thin gannister and flags. Good hill-side exposures occur in the Long Rigg on the east side of East Gill Head, and in a crag, called Little Water Crag, one eighth of a mile south-west of the "G" of Great Punchard Head.

On the hill one third of a mile south of Water Crag a bed of fine flagstones overlies a thick shale with ironstone and some few calcareous nodules. Near the base of the shale there are various thin coals and thick gannisters or fireclays. About 120 yards up the sike, between Long Rigg and Wham Bottom, various thin irregular sheets and dyke-like ribs of harder rock occur in the fireclay; they are perhaps due to infiltration along cracks or joints. About 120 yards below the junction of this sike with another there is a thin calcareous sandstone in which an occasional crinoid fragment has been found. All the above beds are higher in the series than the highest grit, and are preserved here owing to their having been let down between the two east and west faults that bound Water Crag and Rogan's Seat. They are the highest beds seen on the north side of the Swale.

C. T. C., G.B.

(12.) Between Gunnerside Beck and the Swale.

No less than four outliers of Millstone Grit come under this description. The north and south boundaries of the northern patch are by no means of certain character and position, the fell-top being covered by thick peat and occasional Boulder Clay beneath it which obscure geological details. The northern boundary we suppose to be formed by the faults described on p. 172; the southern boundary is generally a natural one. It is separated by at most only a little distance from the northern edge of the next outlier, and possibly may in places run up to it and form a connection between the areas.

The next outlier to the south is bounded on the north by the Hurrace Vein and on the south by the West Arngill Vein which have downthrows in opposite directions, south and north respectively.

The separation of the two most southerly outliers is chiefly due to the South Arngill Vein, which throws down to the north again.

The three most southerly outliers are all formed of the thick pebbly grit usually found at the base of the Millstone Grit. There is a good section in it in the sike at the head of Ivelet Beck, from the letter "G" of "Gunnerside Pasture" northwards; the general dip in the sike is south and not far from the same angle as the hill-slope, so that there need be no great thickness of the bed, in spite of the different elevations of the north and south parts.

In the most northerly outlier the pebbly grit at the base is seen in the east and west sike by Swinnergill Mines, and in a scar on the north side of this sike, to be divided into two

portions by a parting of shale and coal; the parting though very thin is still enough to cause a feature on the hill.

Above this grit there is in a sike at the head of the east and west gill south of Lownathwaite Mines, about 200 yards nearly due east of the grit-base in the gill, a coal at least 16 inches thick, with an apparent high dip to the south-west. This no doubt represents the Tanhill coal, or part of it. We add part of it, for a little further west in the same sike another seam lies directly on the grit with 3 feet of fireclay above it, and there are indications of another coal, perhaps that of the high dip coming on above the fireclay.

Ninety yards south-south-east of Lownathwaite High Whim, by the "L" of "Lownathwaite," there is an old level, which is possibly in the coal. A good deal of coal was at one time got out of the High Whim, but this is said to have been from the seam at the base of the pebbly grit.

In the east and west sike by Swinnergill Mines a fireclay appears just over the pebbly grits, but the section is obscure and does not show whether there is any coal or not. A little above this a feature is formed by coarse-grained flaggy sandstone which can be traced a little distance southwards towards the dam on the fell-top. Three hundred yards north-east of the dam there is a bare feature of much the same kind of rock and probably belonging to the same bed.

C. T. C.

(13.) Surrender Moss and Great Pinseat.

The fairly large outlier of Millstone Grit on Surrender Moss has a roughly triangular shape. Of the portion included in this map the western part of the north boundary is the well-known Friarfold Vein. When this meets Greygame Vein, it is said to follow the latter for some distance and so ceases to bound the Millstone Grit. The boundary seems, however, to be a small vein, forming a prolongation of the large one, for some 200 or 300 yards further east, after which the grit has certainly a natural outcrop.

The southern or south-western boundary is practically a natural one formed by a bold scar of the basal pebbly grit. This rock is here peculiarly massive; it contains the usual number of pebbles and is decidedly felspathic. A noticeable feature is the number of *moutonnée* faces which it presents. It was proved to be 85 feet thick in the Fourth Whim.* At the top of this shaft the Tanhill Coal reposes on the pebbly grit, and is said to be 2 feet 6 inches thick, but it may not be all present here; a little further east it is shaly, but uniformly about 4 feet thick. The position of this coal is not plain on the west side of the hill, but there is a feature showing here and

* Two different shafts have been called the Fourth Whim; oddly enough both commence on the Tanhill Coal. The one here referred to is the Surrender Shaft.

there through the peat which is composed of flaggy sandstones, and which must overlie the coal and represent the bed which comes between the basement-grit and the "Fossil Grit," or at least a portion of it.

The highest beds in the hill probably occur in a small round outlier a quarter of a mile south of the "M" of "Surrender Mine." They are exposed in a small quarry and consist of flagstones lying over shale. The flags and shales above the Tanhill Coal are also seen in two little gills close to the east edge of the map.

Though there are no pits actually in this area the workings to the east probably extend into it underground. These beds are brought down by the Greygame Vein, which has a considerable downthrow to the east.

The small outlier of Great Pinseat consists entirely of the pebbly basement-grit. The rock is exposed in two quarries, one on the west side of the outlier, just south of the Arkendale boundary, the other on the east, close to Wetslaw Head Stone. The outlier seems to be bounded on three sides by faults. The most northerly, which has lately been proved in the Danby Level working, gives the grit on this side a peculiarly sharp straight edge. In working along this a small branch-vein was encountered, which, on being copied from the plan, we found to coincide very closely with part of the west edge of the grit. Its throw, however, was only a few feet. On the south side there is a little ambiguity, because though at the surface the bounding fault is entirely on the Surrender side, it is not so in the Main Limestone. In consequence this fault has lately been proved on the Danby side where it has a throw of 36 feet down north, and followed to the boundary; it was long ago proved on the Surrender side probably as the "Far North," and from Moulds Low Level it was known as "Black Jock." Its exceptionally great hade made it difficult at first to recognise at the surface.

C. T. C., G. B.

The following marine fossils have been obtained from the Millstone Grit of Shunner Fell:—*Chonetes*, *Lingula*, *Orthis resupinata*, *Productus*, *Rhynchonella pleurodon*, Phil., *Spirifera*, *Steleptorhynchus crinistria*, Phil., and *Orthoceras*.

CHAPTER XII.

PERMIAN AND TRIASSIC ROCKS.

PERMIAN.

These rocks represent the next chapter after the Carboniferous in earth-history. Before they were formed those of the Carboniferous system underwent much gentle crumpling, faulting, and general disturbance, and great portions of them were removed, so that Permian beds rest unconformably on various members of the Carboniferous series. Besides this, in this neighbourhood different portions of the Red Rocks are overlapped by others, so that that member which forms the base at one point, thins out or dies off, and another, which overlies it, rests on the Carboniferous rocks at another point. This is a consequence of the irregular surface on which they have been laid. Both of these phenomena point to considerable physical changes going on before and during the time of deposit.

The Permian rocks are more highly developed and show a much greater thickness, and cover a greater breadth of country in the lower course of the Eden than here, where we only get the southern apex of the area. The rocks of this age visible in this map consist principally of brockram (a local name for a breccia of fragments of limestone in a calcareous or sandy matrix). They lie over an area of irregular form representing a rude triangle, at the northern edge of the map, with Crosby Garrett, Natsby, and Whingill near the extreme corners. They form a synclinal fold dipping towards the Eden near Kirkby Stephen.

On the west these rocks are first seen at Crosby Garrett Church Hill. The Church itself stands on Carboniferous Limestone, and the graveyard is partly on that and partly on red shale and sandstone beneath. These give the steep feature, or scarp, which runs round the south side of the graveyard, and are seen in the steep ascent of Church Lane. The brockram occurs a little higher up, but is not very well shown.

Yellow and red brockram and red sandstone dip gently to the north-east in or close to the stream at Benbow Wood. Carboniferous rocks show up in the fields west of a line from here to Crosby Garrett Church, but not to the east of it, and the presumption is that Permian rocks occupy the drift-covered area. A little outlier forms a conspicuous mound in a square field north of the railway and north-west of Smardale Hall. It rests upon a yellow dolomitised Carboniferous limestone. Brockram occurs also in the field immediately east of Smardale Mill.

North and east of this there is a series of exposures of Carboniferous limestones, sandstones, and shales forming an inlet

into the Permian area. The next prominent exposure of breccia or brockram is in a railway-cutting half a mile north-east of Smardale Station, where the beds are well seen. They have apparently been deposited in a hollow, and dip at an angle of about 20° towards the Carboniferous rocks against which they rest towards the east.

In a lane to the north near "Stripes" there appears to be an exposure of yellow brockram. Brockram is also shown beneath Drift in the railway-cutting north of Waitby Level-Crossing. In the lane between this and Waitby red brockram crops out for some distance, but does not cross the Tebay branch-railway until it gets to Kirkby Stephen Lower Station. There is a heavy spread of Drift to the north-east of the line here, but between the station-bridge and Stenkrith Bridge brockram is exposed with a dip to the north-north-east. From this point to Thring Gill and near Wharton Hall sections in the brockram are frequent, both along the river and on both sides of it.

The most southerly patch is intersected by Thring Gill near its junction with the Eden. It is thrown down by a fault ranging north-north-west, and lies upon Carboniferous limestone. Another patch lies west of this fault at the next bend of the river, and a third, on the west side of the river, extends west of the footpath to Wharton Hall. The junction is well seen. The main mass of the brockram shows its base well in the little brow of the road from Thring Gill to Nateby, and above the right bank of Thring Gill and of the Eden below its junction with the gill. The base crosses the Eden immediately west of Nateby.

From this point downstream is a fine exposure of brockram, and in its course the stream passes through some beautiful bits of river-scenery. In its lower beds the brockram is soft and easily disintegrated, but as you approach Stenkrith the rock is strongly cemented with calcareous matter, and as hard and massive as any Carboniferous limestone, which it strongly resembles in bedding, joints, and fracture. The rock breaks across the matrix and enclosed fragments indifferently, and in the weathered joints, enlarged by water-action, hardly exhibits its composite nature; but freshly fractured surfaces show by colours, the limestone-fragments remaining white in a red matrix, how the rock has been built up. The mass is full of big water-bearing joints, and the river wanders along in these by devious channels. The celebrated "Span of Eden" is partly due to a great portion of the water escaping from the main channel and finding its way by side-courses and underground channels. There is probably a thickness of about 200 feet of brockram. The top is to be seen at the foot of Stenkrith, where the brockram dips into a large pool, a pretty sure sign of softer beds coming on, and accordingly we find above it in the banks a trace of shales and many exposures of soft red sandstone, which is correlated by Mr. Aveline with the St. Bees Sandstone.

The brockram has been much quarried for building between the two roads which run to Stenkrith and the Railway Station at the southern end, and it is frequently to be seen along both these roads and underlies nearly the whole of the town. The top of it runs from Corner Dub (Stenkrith) already mentioned by Mell Wood to the milldam of the Upper Mill, where it is seen crossing the Eden. Fine sections of it show in the cliff below the Vicarage, and it is visible almost continuously along the river by the Low Mill to Eden Cottage. In some parts of this the brockram is of a decidedly yellow colour, and looks much dolomitised.

R. H. T.

The upper members of the Permian group, namely the Magnesian Limestone and Plant-Beds, which are developed in Hilton Beck near Appleby, are poorly represented in the southern end of the Vale of Eden. They have been recognised by Mr. Aveline a quarter of a mile north of Hartley, in Hartley Beck, and in Podgill, as mentioned below.

TRIAS.

The area occupied by the outlier of Trias near Kirkby Stephen was surveyed by Mr. Aveline, lately our colleague on the Geological Survey, and to him is due the identification of a soft red sandstone here exposed as St. Bees Sandstone, and the recognition of a marked overlap of the Permian group by that rock. This identification rested partly upon the fineness of grain of the sandstone and its general similarity to the St. Bees Sandstone of the district further north, but more especially upon the presence beneath it of the topmost members of the Permian group, as mentioned above.*

The following description is taken from the notes left by Mr. Aveline:—"The St. Bees Sandstone is well exposed along the banks and in the bed of Podgill, and the River Eden, also in Hartley Beck at Hartley. On the west I believe the St. Bees Sandstone is faulted down against the brockram, which is well exposed in the Eden east of Stenkrith Bridge. As there is no space between where the St. Bees Sandstone is exposed at Corner Dub and the brockram (all beds, such as marls, Magnesian Limestone, and Plant-Beds, being absent) the brockram is most likely the Lower Brockram, although I believe the Upper and Lower Brockram come together further north, the Penrith Sandstone having either thinned away or passed into brockram, which is more likely. On the east the St. Bees Sandstone lies on the Carboniferous Limestone in the bend of Podgill, below Ewebank Scar. Here we

* It is perhaps right to state that these views are not shared by Mr. Tiddeman, who regards the rock as Penrith Sandstone, and attributes its fineness of grain to its having been derived from Carboniferous rocks of finer texture in the southern than in the central parts of the Vale of Eden.

have soft even-bedded sandstone and marly shales, with a few inches of what might be Upper Brockram or Magnesian Limestone, resting directly on Carboniferous Limestone. This looks like overlap."

"In Hartley Beck, east of the railway-bridge, there are a few feet of marly shales below the red sandstone, then a few feet of what may be the Magnesian Limestone. Here it is not clear if there is a fault or not between the Permian and Carboniferous which is highly dolomitised.

"After a later visit to Hartley Beck,* I think it certain that the St. Bees Sandstone and shales overlap the Brockram. At the strong spring on the south side of the beck the St. Bees beds repose on a bed of Carboniferous Limestone, while in the beck below, they rest on Brockram. It looks as if there had been a fault between the Carboniferous Limestone and Brockram before the St. Bees beds were deposited.

"With this complete break between the St. Bees Sandstone and the Brockram, the one overlapping the other, no faults are required,† as I at one time considered necessary."

* Accompanied by R. H. Tiddeman.

† i.e. Between the Brockram and St. Bees Sandstone along the western junction of the two as mentioned above.—R.H.T.

CHAPTER XIII.—METALLIFEROUS MINING.

INTRODUCTION.

The principal metal obtained from the numerous mines within this district is Lead. Under the form of galena this occurs in direct association with faults, either in the form of disseminated crystalline masses scattered throughout the fault-breccia itself; or else in the form of ramifying sheets and strings extending outwards from the plane of the fault into the rock adjoining. Under the name of "flots" veins of the kind last mentioned form an important feature in the mining geology of parts of the district. The galena is usually very poor in silver.

Within the limits of this map the ore occurs chiefly in the calcareous and cherty members, though the associated siliceous strata yield important supplies as well. The arenaceous members rarely afford any regular supply, except where the matrix of the vein traversing the rock extends over an unusual width and is tolerably free from clay. Shales are almost invariably poor.

Hardly any ore has been detected in the Silurian strata, and the Permian rocks, so far as is yet known, contain none at all. The principal ore-bearing beds are in the upper part of the Great Scar Limestone and thence upwards to near the base of the Millstone Grit. Most of the ore yet obtained has been got from a zone, variable in vertical extent, which has the Main Limestone as its medial band. Even on this horizon the veins that have been proved to contain ore in workable quantities are nearly restricted to the south-eastern quarter of the map. Isolated veins and occasional indications of ore occur in other parts, but have proved of little importance.

In the metalliferous portion of the district the mines of Arkendale, Surrender, Old Gang, Lownathwaite, Swinnergill, Beldi Hill, Keld Side, and Lane End on the north of the Swale; and Lover Gill, Muker Side, Spout Gill, Summer Lodge, and Whitaside on the south side, have, in past years contributed very largely to the annual yield of British Lead, while mines hardly of lesser importance have been worked at Stags Fell, Sargill, Beezy, Beldon Bottom, and various places in the neighbourhood of Askrigg in the corresponding part of Wensleydale. Ore has also been obtained, occasionally in considerable quantities, in the Great Scar Limestone adjoining the great faults at Hartley Birket, Bells, and Clouds, but the quantity discovered seems in each of these cases to have been liable to more abrupt variations even than usual.

The mining industry of Swaledale is a very old one. How profitable some of the mines once were is well shown by the immense heaps of "deads" that lie on the fell-top between

Gunnerside Hushes and Hard Level Gill, and by the name of the old house, Merryfield, that lies on the fell at a height of about 1,800 feet. It is doubtless the general rule that the most accessible is the first to be found and worked out, and that thus for the future there lies in store more expense, in the form of longer levels and more pumping, before satisfactory returns are acquired. The readily recognisable veins have all been well tried where they cross rocks that are "kindly," and not too deeply buried.

The system of "Hushing," that is of making a dam and flooding from it along a certain line so as to bare the rocks and make a cut through, has been largely resorted to in times past for discovering and working the veins. The gravel in the beck-bottoms below where the Hushes come in often contain sufficient flood-ore to repay working, and there are now (1882) several men and boys thus engaged both in Gunnerside Beck and Swinner Gill.

The old smelting-places or "Baal Hills" as they are called—a name evidently of ancient origin—are generally found in some breezy hillside situation with a spring near at hand. Several of them occur near Winterings, and there are two about a quarter of a mile east-south-east of Satron.

Here and there small quantities of cerussite have been worked at a profit; but these seem to occur almost exclusively in close proximity to the surface, and are, doubtless, due to the alteration of the common galena. The minerals accompanying the galena vary in different parts of the district. As a rule calcite and barytes with more or less iron-pyrites and zinc-blende preponderate, accompanied in exceptional cases by quartz or fluorspar. Zinc-blende occurs with the galena occasionally in considerable quantities, but the cost of transport on an ore of low value is too great to admit of this mineral being worked at a profit. Calamine occurs, but only in small quantities.

Calcite is far the commonest mineral found in the veins. It occurs in large well-developed nail-headed crystals in strings in the Main Limestone on the north side of Beldi Hill Hush, and in the face of a natural scar crossing Thwaite Beck about 300 yards above the village.

Barytes is common along the course of the Friarfold vein between Hard Level Gill and Great Pinseat. It also occurs in the Old Rake vein (Merryfield), the Blakethwaite vein, &c.

The fluorspar does not usually show the rich colours found in some districts. It has been noticed in the South Arngill vein, the Old Rake vein (Merryfield), the Friarfold vein near Surrender, the Smarber mine, the vein crossing the Swale near the Marble Scar (Gunnerside), the Lover Gill vein, and others.

A little copper-pyrites, with its usual accompaniments of blue and green carbonates (chessylite and malachite), occurs in some of the veins traversing the Carboniferous Rocks; but these occurrences are, almost without exception, confined to the part of the district outside the lead-bearing area. The principal mine where

copper-ore has been worked is situated in the Great Scar Limestone of Clouds, close to the Dent fault.

Various quartz-veins, frequently showing well-developed crystals, sometimes of amethystine quartz, cross the bare plateau of the Main Limestone by High Ing and East House (Grisdale Beck). They make conspicuous ridges, often several yards wide, as they cross the limestone, and contain a small proportion of copper-pyrites, partly converted into the blue and green carbonate. East of High Ing there is an old trial-shaft in the most conspicuous vein.

Similar copper-bearing quartz-veins occur in Mallerstang, and the adjoining parts of Yorkshire, and have been worked or tried for copper near Hell Gill and also under Wild Boar Fell. This ore has been worked on a small scale in Great Sleddale also, and traces of it have led to a few trials here and there over several other parts of the Carboniferous area. A little ore was obtained many years since from the disturbed mass of Great Scar Limestone lying to the east of Kirkby Stephen; but the quantity raised was insufficient to warrant more than a few shallow workings. Copper was also met with in small quantities in working to the bottom of a deposit of hæmatite along a fault traversing the same mass of rocks, but is said to have given place to galena at a short distance down. Some of the ore raised at Clouds occurs in the form of *fahlerz* (grey copper-ore).

Iron occurs chiefly in the form of nodules of clay-ironstone disseminated through the calcareous portion of the shales of the Carboniferous Series. Here and there the abundance of the nodules and the high per-centage of iron in them have led to a commercial enterprise on a small scale. Attempts of this nature have been made near Appersett, west of Hawes, in the shales below the Hardraw Scar Limestone; and again at one or two places near Tan Hill, in the shales lying immediately beneath the Millstone Grit. None of these undertakings have proved commercially successful.

In the form of limonite iron is sometimes found in the veins, especially in the upper part of those veins which extend upwards to the general level of the mountain-tops of the district. Its manner of occurrence is suggestive of its being due to the hydration of deposits of hæmatite.

Hæmatite is confined to the Carboniferous Rocks in the north-west part of the map close to the present outcrop of the red rocks of the Eden Valley. Like the other metals mentioned it occurs either in, or is intimately associated with, faults, and is most abundant in rocks of a calcareous nature. It forms extremely irregular pockets sheets, and strings, extending in all directions along any divisional planes that may happen to occur. Part, at least, of the hæmatite occurs in a substitutional form replacing the carbonate of lime of the limestone. Bedding and other signs of stratification are distinctly traceable into the ore; chert-nodules and other unkindly matter remain unconverted in the mass; traces of corals, encrinites, and other fossils occur just

as in the limestone; and lastly, a transition from hæmatite into comparatively unaltered limestone can be observed, even in hand-specimens. The evidence relating to this subject collected here seems to point to the deposition of the hæmatite having been due to the infiltration of ferruginous matter from the red rocks that once extended far beyond their present limits. Where this infiltration affected the permeable sandstone and shale, the ferruginous matter appears to have been widely diffused throughout the entire mass, deeply imbuing it with iron to a considerable depth from the surface. On the other hand, where it reached the limestone the downward flow could take place only along the joints or any chance plane of division in the rock. Hence the concentration of the ore and the replacement by it of the carbonate of lime took place only along these planes.

In the Swaledale district iron-ore is generally very rare and we have not noticed any undoubted instance of "famped" or decomposed limestones near veins: these rocks are probably closely connected and their absence in Swaledale is striking considering how abundant they are in the adjoining and in many respects similar mining districts of Higher Teesdale and Weardale.

FAULTS AND VEINS.

The mere enumeration of the faults occurring in the area of this map would alone occupy several pages; and would be of little use, as the map shows, better than words can tell, their position and direction. The principal faults from a stratigraphical point of view have already been described. The chief of these is the great dislocation and line of crush which we have termed the Dent Fault (pp. 8, 9, 43-60).

The next important set of faults is that which under the name of the "Stockdale Vein" ranges in an east and west direction along Swaledale. It throws the strata down on the north side, at one point as much as eight or nine hundred feet, and can be traced from the Westmorland border eastwards for some distance beyond the limits of this map. The western part of this fault has already been described in treating of the rocks (pp. 88, 100, 140), and we shall presently describe its course in Swaledale. It is worthy of remark that, although this fault ranges along the dale, it does not seem to have had any direct effect even in initiating the course of the river.

A second important east and west set of faults, with the net result of a throw down south, gives rise to the important series of mineral veins worked from Arkendale westward. The well-known Old Gang Mines are worked along this set. These are described below.

J. G. G., C. T. C.

(1.) Wensleydale.

The Windgates Fault, in the south-east corner of the map, has a downthrow to the east, and ranges from Dowker Hole north-

west to the Summer Lodge Lead-Mines, where it blends with or is cut off by the Summer Lodge Veins. At Dowker Nick the fault throws the bottom of the Crow Limestones against the base of the pebbly Millstone Grit, in which a thin coal-seam has been worked from several shallow shafts. The numerous shafts further south were sunk to follow the fault, which is a vein bearing ore in the Main Limestone. At Brounfield Mine, east of Woodhall Greets, the fault is said to throw the strata down seven fathoms to the east, but it would seem to increase in throw northward. There is here for some distance a narrow strip of the Main Limestone on the upcast side of the vein. Much of the ore about here was got in "flots" and in strings running about north-east on the west side of the main vein. One of these has a throw of 8 to 10 feet.

The Sod Dyke Nick Fault ranges north-east and south-west with a small downthrow to the east. It traverses the Ten-Fathom Grit, which consists of flaggy shales with an intervening bed of compact sandstone. In the cherty limestones beneath the grit the fault was found to bear lead-ore, and it has been worked to a small extent as a vein.

The Beezy Bottom west vein is a fault with a downthrow to the west at the Beezy Hill old lead-mine; but at Stottergill mine it does not appear to have any throw; but a small fault ranging S. 10° W. occurs there, which shifts the outcrop of the Little Limestone. The Oxnop Gill faults are best studied on the Swaledale side, and will be described presently.

The Sargill fault is a downthrow to the east of seventy-two feet near Sargill Lead-Mine, where it has been largely worked for lead-ore as a fissure-vein. A level has been driven along it for a distance of three-quarters of a mile towards Annasett Rigg; it follows the western side of the vein, and runs under the Main Limestone, but at about 1,000 yards from the entrance enters that limestone, and is driven in it.

About 200 yards north of the entrance to the mine an air-shaft disclosed the following section:—

Sargill Lead-Mine.

							Ft.	Ins.
Plate	-	-	-	-	-	-	5	0
Grit	-	-	-	-	-	4 ft. to	6	0
"Douk" (crushed shale)	-	-	-	-	-	1 ft. to	1	6
COAL	-	-	-	-	-	-	-	4
Grit	-	-	-	-	-	-	1	0
Main Limestone	-	-	-	-	-	-	72	0

A little north of the air-shaft the vein takes a sharp bend, and is joined by a cross-joint called Weir's Vein, which has been followed underground.

The fault is seen at Cogill Head, where it throws gannister-sandstone on the east against black shale with nodules and lenticular masses of limestone on the west; the shales contain a 10-inch seam of coal, formerly worked in two pits on the north side of the stream. Further north it throws dark shale on the

east against the compact grit, which forms the ridge known as Peter Rigg.

The Sargill west fault ranges about north-north-west, parallel to the Sargill fault, but is a downthrow to the west. It can be traced from the Underset Limestone northwards to Quarry Hags, where it slightly dislocates the Millstone Grit.

The Sargill Head fault is parallel to the last two, and throws down the shales below the Ten-Fathom Grit on the west against the Main Limestone of Sargill Head on the east.

The Stags Fell fault is the southern continuation of the Lover Gill vein of Swaledale. It cannot be satisfactorily traced south of the Hungry Well on the Hawes and Muker Road, but is well seen in Cat Snout Gill and thence northward for about a mile, the Main Limestone on the west abutting against lower beds on the east.

J. R. D., C. E. R.

(2.) Swaledale.

The Lover Gill vein has a large downthrow to the north-west, and near the foot of Lover Gill throws the top of the Underset Limestone on the north-west side some distance below the base of this bed on the other side. Where it crosses Lover Gill it must be in two parts, or else have a reversed hade, for the main break crosses the gill west of the row of old shafts. There is room in the gill for another break along these shafts.

In the north-east "hush" there is, about five yards east of the chief fault, another shift with a downthrow of 2 or 3 feet in the opposite direction, that is, to the east. Strong strings of fluorspar are also seen 10 yards off on the east in the south bank of Cliff Beck. Where it crosses this beck the throw causes the top of the Middle Limestone on the east side to lie below the base of the Five-Yard Limestone on the west.

The two veins, each with a westerly downthrow, which cross Thwaite Beck close together, some 220 yards west of Thwaite Bridge, are supposed continuations of the Lover Gill Vein: the more westerly vein throws the Simonstone Limestone into the stream on the west side against sandstone some distance below this limestone on the east side. The course between Thwaite Beck and Cliff Beck is for the most part obscure, but there is, 200 yards north of Cliff Beck, what seems to be a small exposure—perhaps an outlier—of the Five-Yards Limestone, brought down by the fault against the lower part of the Middle Limestone.

It is hard to interpret the ground satisfactorily on the west side of Oxnop Beck. West of Hole Bottom it is necessary to suppose three faults, all roughly north and south: one within 60 yards of the beck with a downthrow west to account for the presence of the "red beds" (above the Main Limestone) in Force Beck (the east and west beck south-west of Hole Bottom), while the Underset crops out in Oxnop Beck close by, the Main Lime-

stone being apparently omitted ; another not far from the sharp bend in Force Beck with a downthrow east, to account for the presence of the Main Limestone in the lower part of Shawden Gill (the gill to the west), though the "red beds" in Force Beck have a westerly dip ; and a third west of the road with a downthrow east to explain the Shawden Gill exposure of the Main Limestone being suddenly lost on the west, and beds under the Underset Limestone occurring instead.

Of the faults on the east side of Oxnop Beck, the two on the north running west-north-west are both quite clear as they pass through the Main and Underset Limestones. The others make little or no show on the surface. We drew them in company with a miner who had received much information from his forefathers. Some of the mines near here, are said to have been wonderfully rich, but the ore lay chiefly in "flats."

The Stockdale Vein.—This, one of the largest and most persistent faults in the Quarter-Sheet, is named from Stock Dale west of Thwaite, where it was formerly worked. It has not been tried in many places and is generally supposed to have too great a throw to be a promising ore-bearer. The most recent trial, on the east side of Gunnerside Beck a quarter of a mile above the village, did not meet with much success.

From the eastern margin of the map to Gunnerside Beck the beds on the north or low side of the fault are characterised by a steep southerly dip, whereas those on the south side are almost horizontal. Hence though there is a large throw a gradual flattening of the beds on the north side would speedily diminish it.

At Stony Gill Hole, north-east of Brownsey House, the downthrow north is probably 300 feet or more, as it throws out nearly all the beds between the base of the Main and the Five-Yards Limestones. At Barf End the Main and Middle Limestones are thrown side by side.

About 160 yards west-north-west of Brownsey House there is an old shaft in the vein. A more recent level, 80 yards or so north of this shaft, starts considerably on the north of the break, in the chert above the Main Limestone. The level 100 yards north of Barf End is also on the north side of the vein.

On the west side of Gunnerside Beck the vein disappears for some distance under Drift, but there is a good section of it 300 yards above the foot of Ivelet Beck. On the east side of the beck a recent slip has exposed the crushed rock ; the hade is to the north and considerable. The beds on the north are almost flat but on the south they are much disturbed : about 20 yards in this last direction there is a parallel crush and the sandstone is twisted and splintered. The lowest bed seen in the beck on the north side is the top of the Middle Limestone, and this lies against the sandstones and shales below the Hardraw Scar Limestone.

On the east side of the Swale, near Muker, the break can be localised to within a few yards. The Hardraw Scar Limestone

on the south side of it abuts against a strong sandstone below the Five-Yards Limestone: the sandstone dips at 23° to the south-south-west, but the limestone lies almost flat. The high southerly dip on the north side has doubtless greatly helped to produce the landslip on the south of Kisdon.

In Thwaite Beck there are two parallel faults 20 or 30 yards apart. They appear each to be from 5 to 8 yards wide. Both hade to the north, but the southern one appears to have the greater break—throwing the Main against beds a little above the Simonstone Limestone. The beds near are much confused and stringed with calcite: those on the north side dip steeply south-south-east and hence again considerable landslips have ensued.

Veins between Lownathwaite and Swinner Gill.—Between 230 and 300 yards east-south-east of Lownathwaite House the lowest Millstone Grit with its usual pebbly character abuts against the hard more finely-grained Ten-Fathom Grit. The normal distance between these beds is in this locality nearly 100 feet, and it is hard to account for their proximity without supposing a large fault with downthrow to the south. No such fault indeed appears to have been noticed in the Dolly level, which is now inaccessible, but we are unable to explain the surface-indications without supposing a fault much in the direction of the one suggested in the map. We have supposed this fault to cross the Lownathwaite north vein near Lownathwaite House, and then to run for some distance almost due west. For several hundred yards beyond the house it forms a bank facing north, strewn over with blocks of pebbly grit, as if this rock were nearly in place; on the north of the bank about 300 yards from the house a feature covered with loose chert strikes against it.

Possibly the fault is the same as that generally called "Lownathwaite Great Break." This was met with in the workings, nearly 500 feet below the surface, at a point about 340 yards west-south-west of Lownathwaite House. It was of considerable width and full of black "dowk," looking very unpromising for ore. The direction is given as $S. 33^{\circ} E.$ A large downthrow to the west was proved, the sandstone below the Underset on the east side being brought against the Main Limestone on the west. It is certain that the position deep down in the level is not the same as at the surface, for the base of the Millstone Grit is readily traceable between Lownathwaite hushes and the east and west gills south of them, and no great fault could cross it without observation.

Between Lownathwaite High Whim (by the "L" of "Lownathwaite") and the Swinnergill scars the fell is greatly obscured by peat, and occasional Boulder Clay beneath it, and the course of the veins is doubtful. In the Swinnergill levels the three chief veins, North, Middle, and South, are said, after proceeding a certain distance east, to have met a vein called Field Marshal vein coming from the west-north-west, and then to

have run along it for a considerable distance before they separated. After separating their directions have a considerable northerly trend in them, so that they do not point at all directly for Lownathwaite. We have accordingly adopted the supposition that they meet another west-north-west vein known at Hind Hole, and again run along it for a certain distance, and that when they separate they run more nearly due east. As in Lownathwaite, so too in Swinner Gill, parts of the mines are so deep under the surface that owing to the hade the positions of the veins in them are far from coinciding with their surface-positions.

The base of the Main Limestone for 200 yards north of the Lownathwaite North Hush is marked by a level feature and line of springs. But suddenly it becomes obscure, and in the hush, 100 yards or so further north, lies at a considerably lower level. Whether this is due to some fault or to a sudden change of dip is not clear, but even in the latter case there may also be an accompanying break. An old miner tells us that he remembers seeing a break in the beck-side, about 100 yards north of the mouth of Priscilla level (close by the west side of Gunnerside Beck at the foot of the North Hush), but it is not seen now.

A little below the road, a mile north of Barf End, the base of the Ten-Fathom Grit suddenly gets lower to the north. The surface-appearances strongly suggest a fault, and there are three old shafts close by which have been sunk in expectation of one. The mining-agents too always considered there was a fault here, until the underground workings, at no great depth, proved there was not. The Victoria level, which starts by the "O" of "Old Gang Smelting Mill," is driven 300 yards west-south-west of the place in question, and did not find anything except the Watersikes veins, both of which throw down south-west, or in the opposite direction to the change of level; the Victoria level was in hard rock where it should have crossed the apparent fault. The extreme south-east workings of the Watersikes North vein should also have proved the eastward continuation of the apparent fault, but found nothing.

A fault is suggested proceeding from the Hurrace vein south-east of the Ordnance Station, 1856, near Jingle Pot Edge, and running thence close by this station. The pebbly grit-feature on the east of the hill is well marked, but about 60 yards south-east of the Ordnance Station it either suddenly changes dip, and runs down south, or else is thrown into a lower position by a west-north-westerly fault with a downthrow west. It is not clear which is the case.

The Main Limestone, a quarter of a mile north of Winterings, appears to be thrown down to the north about 10 feet. The base is not actually seen on either side owing to a talus of broken limestone, and we should not have drawn a fault if there had not also been a nick in the scar, such as faults often make, and a shift also in the chert-features above the limestone.

The Whitaside vein is well known in Quarter-Sheet 97 N.E. It has been proved in two levels on the east side of Summer Lodge Beck near the "d" of "Lodge," and has still here a large downthrow south, throwing out most of the Middle Limestone. It has not been produced west of the beck because for a long way this side is entirely obscured by Boulder Clay. Beyond this Drift-area there are two faults, either of which, as far as position and direction go, might answer for a continuation of it, namely, the one that passes through the first "H" of "High Hangers," and the one a little north of this, by the North Gate. But the latter is said to throw down to north about 6 feet, and the former too appears to throw in this direction, whenever any throw can be ascertained. So we cannot well correlate either of them with the Whitaside vein.

In the Marble Scar, Gunnerside, there is a section of a fault running almost horizontally: it has certainly some throw but on what side is not clear. In the bed of the Swale near by there are several strings of calcite, fluorspar, and galena running east and west, through the limestone below the Hardraw Scar Limestone; these are often supposed to be continuations of the veins seen in Gunnerside Beck about 100 yards above the bridge.

Under the outcrop of the Middle Limestone in Routin Gill, Muker, there are limestone-exposures with strong strings of calcite and vein-stuff, apparently pointing south-east. But the exposures are much broken, and the dip variable, and as there is a well-defined slip-head close by on the east side of the gill, they may be but slipped masses. Hence it is impossible to say what the true point of the vein is.

Three-quarters of a mile south-west of Augram there are two exposures of chert, one above and the other below the Ten-Fathom Grit, and each with an abnormally high dip slightly west of south. The ground is too much obscured by Boulder Clay to afford satisfactory evidence, but we have suggested a line of fault running at right angles to the dips.

On the south side of Ivelet there is a remarkably sudden bend-down of the beds to the south, well seen along the road leading from the village to the old bridge over the Swale, near the foot of Oxnop Beck. Just where the change of dip occurs, a crack, filled with crushed shale, breaks through the beds in one place. It is scarcely an inch wide, and of doubtful, if any, throw.

The West Arngill vein throws down to the north just about the entire thickness of the Main Limestone. It has, however, a distinct hade to south-west, that is, a reversed hade. West of the foot of Easter Gill there are no surface-indications of a continuance of throw, and we may consider that the east-north-east veins (veins of White Wallis scar) coming in with opposite throw practically neutralize it. Still it is possible that the vein may continue as a break, even if with no appreciable throw, and it is said in support of this supposition that the Cat Rake level (100 yards north-west of Keld), after following the vein

seen at the level-mouth for about 120 yards, met with another one coming in from the south-east, by which the first vein was deflected to that direction.

The Blakethwaite vein proved excessively rich near the head of Blakethwaite and it is often discussed how best to drive to it so as to drain the workings and open out fresh ground. A favourite idea is to drive north along the Blind Gill vein until Blakethwaite be cut, there being thus a chance of getting good returns even in the preliminary part of the work.

Within the Arkendale royalty it is known as the Bishop's vein. The eastern termination of this vein was proved on Wham Edge by the series of shafts, &c. due north of the quarry in the Crow Cherts by the peat-road. The Crow Limestone is a little dolomitised, but no vein-stuff or throw proved, so it may be said to commence just to the west. There are two branches of it in the boat-level, the northern one of which is just under Bishop shaft and has a throw of 9 feet down north.

The vein enters the Swaledale ground from the east at Little Punchard Head and runs nearly due west therefrom. At the head of Gunnerside Beck it throws the Tanhill coal on the north a little below the base of the pebbly grit on the south. A few hundred yards west of the beck it appears to branch into two, each with a downthrow north. The northern branch throws the grit 300 yards west of the beck into the beck (at a place called the straits) and then crosses the watershed a little south of Wham Bottom. About 275 yards east of where it is supposed to cross, there is an exposure of iron-stained clay—perhaps in the vein—and the shale on the north dips steeply northward at right angles to the direction of the fault. The Long Rigg grit is the same as that in the gill a quarter of a mile above East Gill Head, the fault passing between them. At East Gill Head the fault is exposed on the west bank of the stream and throws one of the grits (the third counting from the basement-grit) rather over 15 feet up on the south side. The little rootlet-gannister above the grit has a very clear outcrop here and is also thrown up to about the same extent. After this, this branch seems to join the one next south.

The southern branch does not show clearly until it crosses the shelly sandstone half a mile north-west of Rogan's Seat. The throw at this point may be about 30 feet; there is a discordance in the dips on either side, that on the south being almost nil, while on the north it is steep to the north-west. A little further east this branch itself splits into two, each with a downthrow north. The northern part is still marked for some distance by a discordance of dips. The southern part has nearly flat beds on either side; it is seen clearly in East Gill and has a throw here of perhaps 40 feet, bringing the gannister-bed near the top of the Yoredale Series against the base of the Millstone Grit on the north. Westwards it passes just north of Frith Tarn, the southern edge of the hill above being quite straight and evidently a line of fault.

On the eastern side of West Stonesdale these two parts can also be inferred. The northern part ends the grit-feature 100 yards south of Lad Gill, and throws it into the gill 100 feet or so. The southern passes just south of the grit-quarries about half way between Lad Gill and Low Brown Hill, and has also been proved at a considerable depth below the surface in the Stonesdale Moor Mine. The engine-shaft (by the "1" of "Stonesdale Beck") starts a little below the Ten-Fathom Grit, and is sunk 299 feet down to the top of the Underset Chert. From the shaft-bottom a crosscut was driven slightly east of north until an east-north-east vein, with a downthrow north of 3 or 4 feet, was met. This proved rich for some distance and it was risen in to near the surface, and then driven along eastwards until it met the southern part of the Blakethwaite vein. This latter vein was then followed eastwards for some 200 or 300 yards, but unfortunately no ore was found: the workings were in the Main Limestone on the south or upthrow side and in the Main Chert on the north. The amount of throw was from 7 to 9 fathoms. A small fault of 1 or 2 feet downthrow to the north was proved about 60 yards south of and parallel to the vein.

It is not unlikely that the two parts of the fault seen south of Lad Gill unite again near the foot of the gill. At all events as we trace the lines from the east towards this locality they seem to be gradually approximating.

West of the West Stonesdale Valley the break cuts off sharply the well-defined flaggy grits (the first grit above the basement-grit), which form Robert's Seat Band, and then it curves round the south side of Cæsar Hill, which is strewn with fragments of the next grit above. This bed rests in the great hollow against the base of the Millstone Grit, and as we know from the coal-borings at Punchard that the Tanhill coal is some 250 feet below the base of this bed, the throw in the hollow is equal to 250 feet added to the united thicknesses of this bed and the basement-grit. The throw must then at this point exceed 300 feet.

On the west side of Graining Scar the break is still greater, for the basement-grit is in contact with a still higher grit. It then seems to meet another powerful fault on the north and is to a great extent cut out, but possibly continues with a small throw that cannot be traced at the surface.

The Hurrace vein is seen in section in the east bank of Swinner Gill, not quite a quarter of a mile above the foot. The breccia filling it is about 3 feet wide, and consists chiefly of fragments of limestone, cemented together by calcite. The sides are vertical. It has a large downthrow to the south, the base of the Main Limestone on this side lying against the base of the Underset on the north. The limestone on the south side is flat, and contains many parallel calcite-strings. The sandstone and shale, on the north, incline slightly southwards when within 3 yards of the vein. Close on the west side of the gill the break appears to be in two parts, and contains a limestone, probably the Underset.

The fault on the north-east side of Beldi Hill is marked by a valley, and the valley on the north side of the hill may also be considered due partly to this, and partly to the Swinnergill veins. Between this valley and East Gill the Hurrace vein, and some of the Swinnergill veins, are generally supposed to come together, the latter running along the former for this distance. West of East Gill the chief break takes a sharp change of direction, and divides into three parts. Many miners consider these to represent the Swinnergill veins separating again, and suppose a fourth vein to continue north-west from the scar with the direction of the Hurrace vein, but of this there is no clear evidence.

In the scar above the mouth of the Cat Rake level, near Keld, there is a split running south-west from the chief vein. The split throws the beds down southwards about 4 feet, but fades to the north at a considerable angle.

Near Green Sike, east of Gunnerside, the Middle Limestone is thrown down to the west by a vein running north-north-east, which was followed by means of a level, starting a little above the high road, to a little beyond the house. In the sike south of the house the sandstone abutting against the limestone on the west side of the vein dips at 20° to the south-south-east. The cheek of the vein is exposed clearly as it passes through the Simonstone Limestone half a mile west-south-west of Green Sike.

Two faults may be clearly made out in the Arkendale side of Great Punchard Head. After crossing the boundary the main gill splits into two. One branch runs nearly due north, and re-enters the Arkendale royalty. Ascending this stream we pass thin flags and shales rising at about the same rate as the channel. The gill now turns sharply westwards, and enters a series of well-marked beds. First we pass two thin flaggy grits, the features of which both seem faulted off to the north. A little further uphill the same two beds are again clearly faulted up; close to the upper one some smashed shale lies on edge close against the fault. The throw here must be nearly 50 feet. A break of 16 feet was cut in the coal-level, just in the line of this fault, and probably forms the continuation of it.

The stream now breaks into two, and near the south branch blocks of gannister like grit are seen, probably belonging to the highest grit, while close to is the shale some distance below the grit. In the other branch the little gannister above the next grit below (the Fossil Grit) crops up dipping steeply, while close to this again are the two little flaggy grits evidently thrown up alongside it. The two thin flags may be followed round the north of Water Crag, and coalesce here to form the Fossil Grit.

After crossing to the Swaledale side these faults coalesce and form the fault bounding Water Crag on the south. The massive grit and gannister of Water Crag are the same as those of East Gill, a quarter of a mile above East Gill Head, and of a crag 100 yards south-west of the "G" of "Great Punchard Head."

A quarter of a mile south of the Ordnance Station 2,176 there is a gap crossing the watershed, which is probably due to the fault; on the north side of the gap is the strong Water Crag grit, on the south shale with ironstone-nodules, capped by thin flags. About East Gill Head the throw is not as large as appears at first, for the difference in level is partly caused by the southerly dip on the south side of the fault. At Raven How the beds are tilted evidently under the influence of the break. From this point its position is obscure until it cuts the Fossil Grit, which it throws down about 30 feet. In one of the little branches of Lad Gill it causes a smash in the shales, and soon after this appears to join the large fault crossing Tarn Rigg between East and West Stonesdale.

North of Lad Gill there must be a fault with a downthrow south of about 50 feet. For a few yards south of a level driven in the hill side just above the Tanhill Coal, the great mass of grit above the coal forms the banks and bed of the stream at a lower level. This fault is doubtless cut out by the northern Tarn Rigg Fault which has an opposite throw. It must split up almost directly to the north-east into a number of little breaks, found when working the coal in this direction from the low level. A fault, which probably has no great throw, crosses the bend of the old road close to the Lad Gill sandstone-quarry. The beds dip down the hill, so that the fault, though small, causes a considerable shift of the outcrops. This fault is possibly the same as the more northern of the two shown north of Potshaw Gill, on the west side of Stonesdale. The base of the Millstone Grit is so obscure that we cannot here determine the amount of the shift, but at Thomas Gill Hill we recognise the upper part of the Tanhill Flags, while in the little stream at the south foot of the hill the Fossil Grit crops out, from which we infer a displacement of at least 75 feet, if not more. Further down this little gill, Caesar Gill, this fault throws the shales just above the Fossil Grit against the little calcareous nodular band (p. 156), a shift of nearly 100 feet. It next cuts off the Water Crag grit on the north side and afterwards probably meets a large fault shown to the south, the two nearly cutting one another out.

C. T. C.

(3.) Arkendale.

The ground about Danby End in Arkendale is much broken up by faults. The Great Blackside vein enters this area just north of the Arkendale boundary and passes close to the old reservoir. The Fourth Whim shows that on the south side we have a small thickness of shaly beds above the Tanhill coal on about 86 feet of pebbly grit. A little further west the massive top-chert is seen in a large hole close to a wall, and as the chert is more than 50 feet below the base of the pebbly grit, the throw of the vein may be roughly considered as 140 feet down south.

On Surrender Moss the Great Blackside vein is also called the South Mid vein. After reaching Grey Game it is supposed to go off along it, their throws practically neutralising one another for a certain distance, after which it starts off again separately, with its former direction and large throw, as the Friarfold vein. At each sharp change of direction a comparatively weak vein appears to keep on in the old line.

In the Arkendale mines a fault having a downthrow north of 36 feet has been proved just under the stone at Wetshaw Head. This was in the Main Limestone: the large hade of the vein brings it to the surface well on the Surrender side and it here forms the southern margin of the Millstone Grit of Great Pinseat. It has been proved to rapidly lose throw going west, but it could not be followed east as it crosses the royalty. Owing to the bend in the boundary-line, however, it once more enters the Arkendale side under the name of the "Black Jock" * vein. It has yielded much lead-ore in the Main Limestone and accompanying beds.

Parallel to and a little north of the last is another vein having a throw of 9 feet down south. At the surface it bounds the northern edge of the outlier of Millstone Grit at Great Pinseat. This too has been fairly productive.

To the north of this is Luck's All vein. The usual throw is only some 9 feet down to the north-east, and it can only be noticed at the surface where joined by Dam Rigg vein and the Sun vein, both of which are lost in this vein. It is easily seen that on the top of the hill the Crow Limestone is thrown against the higher Crow Cherts, but this large throw is quite local.

Dam Rigg vein all along its course throws the Crow Cherts against the Ten-Fathom Grit. The pits and the shape of the ground show the position clearly at the surface. The throw in one place was proved to be 72 feet down south.

Sun vein runs parallel to the last and has only a throw of 4 feet down to the north. Its position has been recorded on the map entirely from mining information.

Cocker vein cuts the Red Beds in Little Punchard Gill, and has been proved in Punchard Level, also known as the Boat Level. Westward it has been found in Cocker High Shaft, where it throws the Crow Limestone up on the north side nearly 20 feet. In a direct line with this vein there is a disturbance in the Top Cherts, which, however, are not actually faulted. There seems no reason to suspect a fault cutting the Millstone Grit. To the east the vein has been followed for some distance, but it gradually becomes a mere string, which joins Luck's All vein mentioned above.

Just west of Cocker Low Shaft a small vein, Shaker's vein, was encountered. It runs rather west of north, and joins Wharton's string, which was also proved in the workings from the Boat Level. This last vein no doubt forms the continuation of the

* A common miner's term for zinc-blende.

fault that so clearly cuts the Millstone Grit some 200 yards south of the Coal-Level, where it throws down north at least 50 feet. To the west this vein appears to die away in a sharp bend of the beds, as may be seen in the south side of the stream further up Great Punchard Head. It may be remarked that the veins seem to bear but little ore about Punchard Head.

In Great Punchard Gill a fault cuts the Main Limestone and throws it down some 15 feet to the north. It would appear to die out to the west before reaching the Ten-Fathom Grit, or at any rate its throw is too small to be detected at the surface. But to the south-east it rapidly increases in throw, and in Little Punchard Gill brings the base of the Main Limestone against the Underset beds. In a level driven a little further down the hillside the vein proved practically barren. Continuing in the same direction it splits into two; the southern branch crossing close to Rowantree Holes, for the cherts crop out below the upper part of the Main Limestone. The north branch has been proved in some levels close to the limestone-quarry, and repeats the outcrop of the upper part of this bed. It is probable that both branches die out further east.

Near Routh End, Arkendale, there are two well-marked faults, both shown by the Routh quarries in the Underset Limestone. The northern one is also marked by the base of the Main cherts at Routh Top being thrown up against the base of the Red Beds, as is well seen at a little level. It certainly continues as far as the top of the Red Beds, and seems to cut the base of the Ten-Fathom Grit close to the "Standard Man." The second fault is parallel to the first, but has a smaller throw; it does not seem to extend to the top of the Main Limestone. A level, starting close to the limestone-quarry and driven towards these faults, soon met a small vein which seems to bend about in an odd manner and has but little throw. It is possible that the Routh North vein may join this and be the small vein shown just under the Standard Man. Very little lead was met with, the beds north of Great Punchard Head not being prolific in this neighbourhood.

G. B.

(4.) Various nearly horizontal faults.

It is a common mining experience that veins in horizontal strata vary in hade greatly, and that they sometimes, especially at the bottoms of hard beds, run horizontally for a certain distance before breaking through the bed above. In the sike about half a mile north-west of Blakethwaite Smelt Mill there is a section that shows both a clear fault with a hade approaching horizontality, and a horizontal line of junction of beds which also is in all probability a fault. On the north side of the undoubted fault there is chert resting upon fireclay over shale, on the south side all shale. The throw and hade are to the south. On the upper side of the horizontal junction we have the same chert, and shale above, both dipping steeply north, and on the

low side the fireclay and shale below, both lying nearly horizontally. At the junction itself is about half an inch of grey clay, like crushed shale or "douk." Another horizontal vein in the Marble Scar, west of Gunnerside, is described on p. 174.

In East Gill about 60 yards below the south part of the Blake-thwaite vein there is a fault in shale with a southerly hade, approaching the horizontal. The Barbara vein, on the east side of Gunnerside Beck, also has a great hade.

In Mossdale Gill, Wensleydale, about 180 yards above Mossdale Head house, strong strings and nests of calcite and yellow fluorspar, which run nearly horizontally, are exposed in or close to the bed of the stream. On the west side of the stream they have a great hade to the west. The vein to which they belong must have some throw, for it brings up a dark sandstone through 3 or 4 feet of the lower portion of the Simonstone Limestone.

C. T. C.

CHAPTER XIV.—COALS AND BUILDING STONES.

(1.) COALS.

The principal coal seams worked in this area occur in the higher part of the Yoredale Series and the lower part of the Millstone Grit; other and less important seams also will be referred to here in the order of their formation.

Traces of coal occur in association with the sandstones occurring in the topmost beds of the Great Scar Limestone in several localities; but none of them much exceed an inch in thickness, and they are often represented by little more than a mere smut, or by scattered carbonized remains of vegetable origin. In the Yoredale Series coals, also very thin, generally occur in the sandstones and shales which separate the Hardraw Scar and Simonstone Limestones; but although these seams may be detected in nearly every well-exposed section, none of these ever assume any economical importance.

In the next group of sandstones and shales one or more seams of coal commonly appear, and the higher of these, namely, that just below the Middle Limestone, has been worked over a large area chiefly for lime-burning and similar purposes, as it is generally too impure and sulphury to be of much use in the house. This is the seam which was once worked so much about the Moor Cock Inn near Hawes Junction, and that was described by Phillips under the name of the "Coal of Lunt-y-Thorn." The greatest thickness attained by this seam is about 18 inches, but one foot is nearer the average.

In the next group of limestones, sandstones, and shales, overlying the Moor Cock Seam, two or three unimportant seams are traceable, but none of these have been considered worth working. Beneath the Underset Limestone, however, and at a variable distance from it, occurs a coal-seam that eventually develops considerable importance towards the north-west. It can be traced over nearly the whole of the area of the map, but is not worth working except over the western third of the Carboniferous area. In Garsdale, and in the region lying to the north-north-east it has been worked at intervals, and at one time formed an important source of the local supply. Old pits are dotted along its outcrop around Baugh Fell, the west side of Swarth Fell, Wild Boar Fell, Mallerstang, Tailbrigg, and Nine Standards, near Kirkby Stephen; and under the name of the Borradale Seam it is even yet worked for such purposes as its quality is adapted for.

The next higher seam occurs at the base of the Main Limestone. This is the "Coal of Cotter Fell" of Professor Phillips

from the name of the fell where it was most worked. Like the last-named seam it is remarkably persistent, although variable in thickness and character. About one foot seems to be its average thickness where it has been worked at all.

Where the arenaceous type of beds associated with the Little Limestone is fully developed the sandstones under the name of the "Coal Sills" usually bear at least one seam, or its representative. This has been worked here and there along much of the higher ground lying to two miles or so on the east side of the Dent fault, and it eventually develops into a seam of considerable economic importance beyond the northern limit of the map.

Coal has also been found in the Ten-Fathom Grit, but its value does not appear to have been set very high generally. The principal coal-seams occur in connection with the grits of Howgate Edge and Humesett. There are two seams, one above each of the two grits. Both of these have been worked in various places, but the more important is the upper one. This is the Tanhill Seam which for many generations has been the principal fuel employed for household purposes. The coal ranges in thickness from a mere smut up to about 50 inches, and is generally of fair quality. It has been worked in different places over nearly the whole of the Carboniferous part of the map. The two chief localities after Tan Hill (described on pp. 153-155) where it has been worked are the Kettlepot Colliery in Westmorland, and on Fossdale Moor and Cotterside in Yorkshire. On Fossdale Moor there are three coal-seams, the principal of which was described by Sedgwick under the name of the Turna Fell seam, and considered to be the same as the Tanhill seam. A seam believed to be the same has also been worked on Muker Edge, and to a small extent at the head of Gunnerside Beck, and is known too in many other spots on the north side of the Swale. This coal also occurs just at the top of the section in the Fourth Whim by the Surrender Mine. A coal believed to be on the same horizon was also once worked on Baugh Fell.

Professor Sedgwick well remarks: "As not less than three beds of coal are found here and there subordinate to this group (the lowest Millstone Grit), it would be impossible to prove that in all the above-mentioned places the coal is precisely upon the same parallel. It is, however, so considered by the miners of the neighbouring districts."*

A coal-seam near the base of the Millstone Grit was, and is, still being worked under Mallerstang Edge (p. 141), and other seams occur here and there throughout the higher members; but none of these have been much turned to account, and since the introduction of railways the local supply has to a great extent given place to that from the regular coalfields. The Tanhill Seam, however, is still used in the wilder parts of the country.

* *Trans. Geol. Soc.*, vol. iv., p. 82, 1835.

We have already noted that peat is used in the smelt-mills, as well as for household purposes.

Fireclay, as a rule, is not found below any of these coal-seams, but the associated strata, both above and below frequently contain abundant traces of vegetable matter. Rootlets of *Stigmaria* are of common occurrence in many of the sandstones and fragments of *Calamites*, *Sigillaria*, and *Lepidodendron* are fairly abundant in the same beds. The vegetation traceable in direct association with the coals is usually in the form of linear-leaved plants, without any trace of the fern-like fossils found in such profusion in the coal-bearing strata of other localities. Distinct traces of lamination are observable in most of the seams, and all of them are liable to be split up by the interbedding of sandstone or shale.

Lastly, there is a marked association of the coal-seams with beds of limestone with marine fossils, which come on either a few feet above the seams, or else, very frequently, set in at, or about, the same geological horizon at no great horizontal distance.

J. R. D., J. G. G.

(2.) BUILDING STONES.

The Silurian Rocks of this district furnish an inferior kind of building-stone, which under the name of "Whin" or "Blue Whin," is employed in the vicinity of the quarry for farm-buildings and similar purposes. Most of the material of this kind is obtained from the Coniston Grit.

Here and there the flagstones of the Coniston Flags are split up along the cleavage-planes into a coarse kind of slate; but hardly any of the material is of sufficient practical importance to merit more than a passing mention.

The Blue-caster greenstone has been quarried for walling purposes, or occasionally farm-buildings, but the quarries are all too near the surface to touch the undecomposed part of the rock.

The principal building-stones of the district are obtained from quarries in the Carboniferous sandstones. Locally, nearly every one of these sandstones develops into building material of more or less value; but the principal horizons are in the group of sandstones intervening between the Underset and the Three-Yards Limestones, and between the latter and the Five-Yards Limestone. These two groups form the Upper Hawes Flagstone and the Lower Hawes Flagstone groups respectively, so named from the locality where they are most extensively worked, on the north side of Wensleydale, close to the town of Hawes. Flagstones of very good quality are obtained from these beds at Hawes and elsewhere within the area embraced by this map.

In Swaledale proper the chief sandstones quarried are those below the Hardraw Scar, Middle, and Five-Yards Limestones, and that between the Three and Five-Yards Limestones. There are also large quarries up Gunnerside Beck in the Ten-Fathom Grit.

A thinner kind of flagstone used to be largely quarried in years back, and employed under the name of "slate" for roofing purposes, but the cost of the timbering required to support it has gradually caused its employment for that purpose to be abandoned. Now and then the limestones of the Carboniferous series are also employed for building-materials; but houses built of limestone are said to be invariably damp, and moreover, the stone is not easily "dressed."

The sandstones and grits of the Millstone Grit Series likewise yield good building-stone occasionally. One of the best flagstones obtainable from the Carboniferous Rocks of this part is yielded by the second member of the Millstone Grit Series at Hill Top quarry, above Keld, already mentioned in the description of the Millstone Grit (p. 149). Occasionally the coarse pebbly grit of the Ingleborough Grit has been quarried; but it seems less in favour as a building-material than the finer grained and more compact sandstones of the Yoredale Series.

In the neighbourhood of Kirkby Stephen the more compact and better-bedded varieties of the Permian Breccias are rather extensively made use of chiefly as building-stone; but though it forms, when well-selected, a good-looking and durable stone, the material is rarely sufficiently coherent to admit of its being dressed to any great extent. Capital gate-posts are easily obtainable from these beds, and they seem to be in favour for this purpose at a considerable distance from the parent-rock.

J. G. G.

CHAPTER XV.—SUPERFICIAL DEPOSITS.

GLACIAL DRIFT.

Though Glacial Drift occurs more or less over much of the high ground, yet the principal masses as a rule are confined to the lower tracts, whence the Drift creeps irregularly upwards, clinging in gradually thinning sheets to the fell-sides, till it finally dies away in detached patches left only in sheltered spots. On the lower ground the Drift lies more or less in the form of drumlins with their axes nearly parallel to the trend of the adjoining valleys. The drumlins generally give place at the junction of two of the larger valleys to long spits, which gradually thin away as the distance between the two streams increases.

Owing to the thick mantle of hill-peat that wraps the higher parts of most of the fells, the upper limit of the Glacial Drift cannot always be defined with any certainty. Sections here and there through the peat-hags often expose deposits that contain far-travelled or up-carried boulders, which are often as well glaciated as any to be found at lower levels. There is abundant evidence that many boulders have travelled uphill; but whether this implies that the whole of the ice moved in the same directions is somewhat uncertain.

The Drift consists mainly of stiff blue or dark-grey Boulder Clay, and follows the law of distribution so frequently observed in other districts, viz., that the thickest and widest deposits occur on slopes that face away from the source whence the material was carried. Thus in Gunnerside Beck, a little above Gunnerside, there is a considerable thickness of Drift on the west of the beck and scarcely any on the east side, and similarly in Oxnop and other gills.

Considering the great amount of Drift in the country, good sections are not plentiful. Perhaps the best is that in a cutting on the North-Eastern Railway near Kirkby Stephen Station. In the fell-country one of the best occurs in till just above West Stonesdale. Good sections may also be seen in the eastern branches of Mud Beck near Bow Hills where the streams have cut little scars in the Boulder Clay, which is very sandy and stony and contains many boulders of the Water Crag Grit. Fine sections also occur in Arkendale, for the south banks of Arkle Beck give a continuous exposure of Drift for a great distance. These banks are often 50 feet high, showing that the bottom of the Arkle Valley is deeply covered by glacial deposits. As is often the case, the banks of Boulder Clay slide away in wet weather, and frequently disclose large boulders of Millstone Grit and limestone.

The upper part of the Ure Valley, known as Lunds, is more or less overspread with Drift to a height of about 1,200 feet above the sea-level. The upper boundary of the principal mass of

Drift roughly corresponds with the base of the Underset Limestone, but a terrace of Drift generally occurs on the shale between the Underset and Main Limestones, both of which rocks form prominent and, for the most part, bare scars. Thin patches of Drift occur above the Main Limestone as high as the 1,600-foot contour.

The river Ure in this part of its course winds through flat alluvial and peaty tracts, which appear to be the sites of small tarns formed in the spaces between mounds of Boulder Clay. Several of these Drift-mounds have distinct names, as Ling Hills, Shortelick Hill, Green Pot Hill, Cowshaw Hill, Carr Rigg. The name of "rigg" is more often applied to them than that of "hill."

The western slope of the entrance to the Cotterdale Valley consists of Boulder Clay lying in mound-shaped masses, among which we may mention Crook Rigg, High Rigg, Cotter Rigg. Between the "riggs," or drumlins, the Drift is not thick, and the underlying rock is often exposed, as at Curly Sandstone-quarry; the rock emerges also at the base of the Drift in the exposure of sandstone known as Nanny Dunne Table, which throws out a strong spring of that same name near New Piece House.

The eastern side of the valley is much steeper, and holds Drift in patches only on the lower slopes; the outcrop of the Middle Limestone is well exposed like those of the Underset and Main Limestones above it. At Blea Pasture, however, the upper boundary of the Drift rises to 1,400 feet above the sea, on the shoulder separating Cotterdale from the Hearne Beck valley. In the latter valley the Drift rises eventually to 1,600 feet, ascending higher on the west side than on the east, and concealing for some distance the outcrop of the Main Limestone.

The tongue of rough grass-land called Fossdale Pasture and Great Haw consists of Boulder Clay of a pale-yellow tint, with numerous rectangular blocks, chiefly of local sandstone; in places the clay passes almost insensibly into gravel, which occurs in lenticular patches. The Drift rises to about 1,450 feet, and thins off just below the base of the Underset Limestone. On the eastern slope of Fossdale the Drift is practically absent, a narrow terrace only occurring immediately above the alluvial flat which extends from Cloven Gill to the waterfall just above Clough Wood. Below this waterfall a deep rocky gorge extends to the foot of the wood. But when Hearne and Fossdale Becks unite the valley widens considerably; and gives room for a small patch of Drift on the eastern slope above the alluvial flat. In the main valley of the Ure nothing but Boulder Clay was met with in the railway-tunnel near Mossdale Head. The Drift is also very thick immediately west of Askrigg.

Between Cogill and Whity Gill, on the peat-covered tract known as Bodystead, it reaches up to a height of 1,500 feet

above the sea-level. It appears to be here about 60 feet thick. Above Cogill Fold it consists of a rather stiff yellow clay with many fragments of local sandstone, seldom exceeding a few inches in diameter, and all more or less rounded. Below Broadmea, at Bracken Gutter, the Cogill Beck has worn out a steep bank 20 to 30 feet in height, in which the Drift is distinctly current-bedded. South of the stream it forms extensive mounds, which are best seen from an eminence.

In Skell Gill the surface of the Simonstone Limestone is glaciated under tough glacial clay containing many pebbles, chiefly of sandstone, and all of local origin.

The bottoms of Grisdale and Garsdale are more or less Drift-covered; but at the junction of the two and for some distance up the east side of Baugh Fell, the stony clay is so thick as to obliterate all traces of the solid geology. Indeed it is not easy to say to what height the deposit extends in this part of the district, for well-marked local till occurs in Long Gill at so much as 2,000 feet above sea-level. The long watershed between Rawthey Gill Foot and Grisdale is also for the most part thickly covered. There is clear evidence that Grisdale Beck originally joined the Clough close by Hard Ing Bridge, thus flowing several hundred yards west of its present position. The little gorge above Clough Farm was cut by the river in consequence of the pre-glacial valley having been blocked with thick Boulder Clay. In this area we have found no pebbles that suggest an origin from a distant locality, the Drift-materials being apparently all of local origin.

The Drift in the west end of Garsdale consists purely of Carboniferous materials, and is everywhere packed with stones, most of which are scratched. It rises occasionally into drumlins, such as Bellow Hill at the fourth milestone from Sedbergh, and spreads in thick masses over the line of comparatively low ground marking the position of the Dent Fault. The Longstone Fell at the west end of Rise Hill is heavily loaded with great ridges or drumlins of Boulder Clay, the axes of which run pretty constantly in an east and west direction. The distribution of the limestone-boulders shows that the Drift here travelled from east to west; for while boulders of this rock occur (sometimes plentifully as in Hole Beck) on the west side of the Dent Fault, the Coniston Flags have not contributed to the Drift on the east side of this line. On reaching the foot of Garsdale and the other similar valleys the Carboniferous Drift seems to have turned southwards, and not to have spread to any great extent over the Silurian area. The west slopes of Baugh Fell are also thickly covered by Boulder Clay, running up to a height of 1,400 feet above the sea, and it is only in the deeper water-courses that a view of the rock can be obtained. In one instance only has a truly stratified gravel been observed in this neighbourhood. A low esker occurs about 300 yards north of Fell Yeat, consisting, as is seen in some small excavations, of well-stratified sand and gravel. We could not ascertain

whether this deposit was older or newer than the Boulder Clay ; but regard it as probably contemporaneous with, and passing laterally into it. Near Hebblethwaite Hall we notice again that boulders of limestone abound in the Drift, on the west side of the limestone-outcrops.

The country north of Whinny Gill is pretty uniformly covered, and solid rock is rarely exposed save in the bottoms or sides of the numerous streams. On the west side of the Dent Fault the Drift consists of stiff blue clay, containing fragments of local and foreign rocks many of which are striated. But on the east side of the fault the deposit is almost entirely composed of fragments of local sandstone in a sandy or clayey matrix. Occasionally there are foreign pebbles, but they become extremely rare a quarter of a mile east of the fault. So strongly does this surface-deposit resemble decomposed rock that it is difficult to separate mere rain-wash from Boulder Clay.

In the valley of Backside Beck, a clay-drift with fragments of local rocks covers the steep slopes up to an elevation of 1,250 feet. The beck and its tributaries, with the exception of the two first above Benne End in which Drift alone is exposed, have cut through the glacial deposit and exposed the Silurian rocks beneath. In the two excepted becks clay, well packed with stones, overlies stratified Drift with bands of current-bedded sand at about the 1,000-foot contour. At Northwaite the beds are loamy and intermixed with sand, the whole containing a few well-rounded stones.

Glacial Drift ascends the Silurian rocks in the valley between Harter Fell and Clouds Fell to a height of about 1,100 feet above the sea-level, while eastward over the limestone-slopes it occurs at somewhat higher levels, and consists of a dull-red or grey clay with pebbles and semi-rounded blocks of Carboniferous sandstone and limestone, some of the latter being remarkably well-glaciated. A typical section occurs in a pit on the old Sedbergh road, 400 yards south of the Friends Meeting House, marked as a quarry on the six-inch map. Numerous swallow-holes on Black Moss, and the gills between Eller Hill and Nash House, also give good exposures. Higher up in Uldale the Drift creeps up to 1,250 feet, and a patch of local sandstone-drift occurs east of Flint Howe at an elevation of between 1,500 to 1,600 feet.

Hog's-back mounds or drumlins of Boulder Clay are prominent on the south side of the Swale valley between Oxnop Beck and Muker. Their longer axes are rudely parallel to the valley. In the Boulder Clay tract on the west side of West Stonesdale a series of features points in a general direction slightly east of north, and undoubtedly crosses over the beds beneath. Even where there is a no greater thickness than 2 or 3 feet of Drift, a feature, carved out of the thick shales which lie between the Millstone Grit and the Ten-Fathom Grit, runs in that direction. The direction is that in which it appears, from other evidence shortly to be mentioned, that the ice locally moved. Similar

features occur near Tan Hill in the form of long ridges of shale pointing north-east; others of a similar kind, on the fell about a mile north-east of Muker, run slightly south of east.

The dry valleys over the watershed east of Keld (between there and Keld Side) and those on the west side of Cliff Beck, about half a mile south-west of Thwaite, are also perhaps of the same character. The former have an east-north-easterly direction and consist entirely of Drift. The latter run north-east and are partly in rock.

On the west side of Mossdale Beck the general direction of the drumlins and "slacks" or valleys within the Boulder Clay is east or slightly south of east. They thus keep rudely parallel to the depression of the Garsdale Head valley, the Ure valley, and the intervening watershed.

The boulders in the clay are often striated and usually more or less rounded and worn. But in the gill a third of a mile south of Angram and certain other places there are many bits of shale which might be wrongly supposed to be all but *in situ*.

Neither in Swaledale, Wensleydale, nor in the district of Mallerstang have any boulders foreign to the dale been observed, but there are in various places some which must have come from a considerable distance and have been pushed up from lower ground. Thus in the valley of West Stonesdale many big boulders of grey limestone, most of them doubtless belonging to the Main Limestone, lie some distance north of and on higher ground than the highest exposure of this bed in the stream; even as far north as Lad Gill many such boulders occur mixed with others of the "Red Beds." In the Drift in an old quarry in Millstone Grit, 130 yards south of the gill south of the "a" of "Stonesdale Moor" much chert is also found. The above facts point strongly to the Drift having locally travelled rather northwards, perhaps under the influence of ice from Shunner Fell.

The occurrence, too, of numerous boulders of the Water Crag grit at the head of Mud Beck shows that a large portion of the ice-sheet swept over one side at least of this hill, and, moving north-eastward, carried with it large blocks of the rocks it encountered; and the ice-worn fronts of such grit-masses as Alderson Seat show how thick the ice must have been and in what direction it travelled.

On the west side of East Gill, about a third of a mile below the junction at the top of the "e" of "Head," there is a thin spread of Drift which contains much chert. Near the head of the gill west of Little Punchard Head there are many drifted chert-pieces. The nearest chert in place is in Blakethwaite Gill, only a short distance away, and straight to the west in a line for the top of Rogan's Seat, but it lies at a lower elevation than the drifted pieces.

The Millstone Grit on Crackpot Moor and also above Whitaside Tarn is scattered over with chert-fragments which have probably come from lower ground to the west. About 100

yards south-south-east of the Ordnance Station, 1,772, there is a large mass of chert with no constant dip, which has probably been glacially transported. Its extreme length from east to west is about 100 yards, and its breadth scarcely half that, but the boundaries are not always definite. The mass is covered with green, in strong contrast to the heather of the surrounding grit.

Another but much smaller mass of chert, with Main Limestone on either side of it, lies in the sike that runs into Cliff Beck a little below the last "f" of "Cliff." It appears to dip north east at 30°. If in place it must be let down between two faults, but it is probably a transported mass.

In weathered surfaces Boulder Clay often loses much of its fine clayey matter and assumes a sandy or gravelly aspect, as, for example, near Low Oxnop and Kearton's Wood, which makes it hard to distinguish it from the Glacial sands. Deposits of this latter kind are apparently rare, but two ridges of such occur on the south side of the Swale near the plantation north of Mudd House; in the more northern ridge there is a section showing gravel and stiff stony Boulder Clay mixed up together, below which there is said to be sand. Similar ridges occur half a mile south-south-east of Angram, and immediately east of Aygill.

Besides Boulder Clay and sand or gravel there are other varieties of Drift which cannot be properly called either, for example, at the head of the gill south of the "M" of "Melbecks," 150 yards north of the Old Gang Smelt Mill, near Routin Gill-head and Greenscat Beck-head, and along the sides of this latter beck, &c. In the first-mentioned locality it consists largely of fine flaggy sandstone, sometimes in large masses, derived from the flags above the pebbly grit. In the third and fourth it consists chiefly of blocks of pebbly grit. In the last it is from three to eight feet thick, and is composed chiefly of fragments of sandstone embedded in a varying and often small proportion of yellow clay. The sandstone is not pebbly as a rule, but belongs to the sandstones quite close at hand, as if only pushed down a short gentle slope from the parent scars. In such a case as this it is perhaps impossible to say that the bed may not have been produced by the gradual movement of the "soil-cap."

Contortions which are only superficial and of Glacial origin are probably common, but it is not often that proof of their character can be obtained. Those in the shale about a quarter of a mile south-west of the "M" of "Melbecks" we suppose to be due to the passage of ice.

The valley on the west side of Kisdon (Swaledale) is so deep and wide that we cannot suppose it to have been formed by the little stream by which it is at present drained. It must in pre-Glacial times have been formed by the Swale or a portion of it. We say a portion because both East Gill and Swinner Gill join the Swale below the head of the old valley, and it is scarcely likely that they went along it. They would more naturally go

along the present Swale valley on the east side of the hill, and the size of this valley is so large, and the distribution of Boulder Clay on either side of such a character, being thick on the west side but almost absent on the east, that we must suppose it in the main to be pre-Glacial, as well as the old one.

We may then look back to a time when the water of Sleddale, Birkdale, Whitsundale, and West Stonesdale, travelled along the valley west of Kisdon, while that of East Gill and Swinner Gill followed the valley on the east. The "divide" between the two valleys would, near Keld, be only 300 yards or so wide probably, and gradually it would by denudation lose in height more and more, until perhaps it was finally breached by some great flood. We should suppose it to have been only a weak buttress for long ages previously, for there are three east and north-east faults known, which must have crossed it, and three others with a south-east direction which may also have partially affected it.

GLACIAL STRIÆ.

Only a few striated surfaces of rock in place have been observed in Swaledale. There are, however, some very fine instances in Low Row Pasture on the flagstones above the Middle Limestone. The directions of the striæ vary from about E. 4° N. to E. 14° N., that is, they point, roughly speaking, from Great Shunner Fell. There are also some striations on the west side of East Gill, on a fine-grained gannister about a third of a mile south of East Gill Head. The striæ cross one another in these two directions, east and west, and north and south; the former set may possibly be due to a landslip, in the course of which the exposure occurs.

All the outcrops of grit about Tan Hill are in many cases rounded and occasionally scratched, the striæ pointing east by north; as are also the grits of Alderson Seat (incidentally mentioned above) where the direction of striation is north-east. Belonging to the same set of striations are some very fine ones that occur on grey grits (Polly Moss) in Westmorland, near the north edge of the map. There are there two sets of striæ pointing respectively north-east by east and east-north-east. There is nothing in the striæ themselves to show in which direction the ice moved, but the shape of the ground would indicate that the movement was towards the east.

Some fine striæ are exposed on a hard sandstone in the railway-cutting about a mile west of Thwaite Bridge, Wensleydale. The direction varies from east to about E. 28° S., but the average may perhaps be taken as E. 13° S., which is much the same as that of the Ure valley near by. The most extensive exposures occur on the south side of the line: on this side besides the upper surfaces of the sandstone-blocks, their vertical sides that face the north, or the centre of the valley, are also smoothed and striated. The striæ on these side-surfaces generally run nearly horizontally.

A remarkable exposure of a glaciated rock surface has been made in the cutting on the Midland Railway about one mile

south of Hawes Junction. The surface is very uneven and presents many ledges with vertical and horizontal faces, all of which are strongly grooved. The movement of the ice has clearly been from south-west to north-east, that is up Garsdale, though from the general direction of the Drift-transport (p. 188) it might have been supposed that the ice-flow would have been down the dale.

On the brockram near and north of Kirkby Stephen low Station and again in the bed of the Eden, west of the mouth of Podgill, several striæ have been noted by Prof. Hughes and Mr. Goodchild, their general trend being north-east, but in the railway-cutting east of the Station Mr. Tiddeman has observed striæ running south-east.

The top of Baugh Fell, consisting as it does of a hard gannister, has retained a character of great interest to the glacial geologist. Though nearly 2,200 feet above the sea-level, the ledges of rock which show through the peat are rounded and striated in a manner almost unique. The *roches moutonnées* are often nearly 100 yards long, many parts of the surface being polished like glass. The fine striations, too, are beautifully preserved and point roughly north-east and south-west. The scratches themselves do not show in which direction the ice moved, but it is probable that the motion was from the south-west, as in the railway-cutting, for in many places the grit-beds have been turned up almost on edge apparently by pressure from that quarter.

As regards the movement of the ice, one of the most instructive views to be had in any part of England, is that from the Buttertubs pass between Swaledale and Wensleydale. Looking thence southward, across Wensleydale, one sees the gable-ends of the hills between the big dales running into Wensleydale from the south, to wit, Widdale, Snaiholme, and Duerley, massed with Drift trending down Wensleydale across the mouths of the side-dales. One can, in imagination, see streams of ice flowing down each of these dales and turning eastward as they severally join the main stream flowing down Wensleydale.

To sum up this part of the subject it seems that the ice moved down the larger dales, so that its drainage was much the same as the water-drainage is now; but that in the upper parts of the basin of the Swale, where the streams flow generally from north to south, the movement of the ice was generally eastward with, perhaps, a touch of north in it, so that it crossed the line of the present drainage and actually flowed over into the basin of the Tees; and that at one time ice flowed over from Garsdale into Wensleydale, and that probably at the same time the highest hills in the neighbourhood, at least up to nearly 2,200 feet above the present sea-level, were scraped and scored by masses of ice moving from the south-west towards the north-east.*

* "The Glacial Phenomena of the Eden Valley and the Western Part of the Yorkshire-Dale District" were fully discussed by Mr. J. G. Goodchild in the *Quart. Journ. Geol. Soc.*, vol. xxxl., pp. 55-99, 1875.

CHAPTER XVI.—SUPERFICIAL DEPOSITS—*continued.*

RIVER GRAVELS AND ALLUVIUM.

The Alluvium calls for but little notice. The principal extent of it occurs along the southern edge of the map, near the Hawes, where abundance of fine sand and loam is clearly the sediment brought by the Ure into an old rock-basin, the barrier of which is now cut through by the river between Aysgarth and Bear Park.

About the head of Wensleydale, and also near the head-waters of the Lune, about Ravenstonedale, irregular patches of Alluvium occur among the Drift-mounds. These patches seem, in many cases, to occupy the sites of silted-up tarns.

The alluvial deposits of the Rawthey, below Rawthey Bridge, consist of coarse gravel, arranged in two or more terraces.

In Swaledale both the alluvial flats and the higher terraces are chiefly composed of coarse gravel, as we should expect from the gradients of the becks. The size and tumultuous arrangement of the boulders in some of the gravels are very striking.

The high terrace south of the Swale near Gunnerside runs for such a distance beside the present river, and has in many places such an even top and well-defined back—notwithstanding its age and liability to denudation—that we are not inclined to consider it other than fluviatile, though possibly it may belong to a time but little removed from the Glacial Period. There is a corresponding terrace on the north side of the Swale west of Gunnerside. Both these terraces, when traced up Oxnop Beck and Gunnerside Beck respectively, get to be little above the present water-level.

The high terrace a mile or more below Gunnerside, on the south side of the Swale, consists of angular gravel not unfrequently mixed with pieces of shale. Muker is built on a high terrace, and there is another of about the same height, with a better defined outer margin, on the south side of the Swale opposite this village. A high terrace at the foot of Swinner Gill shows in section a considerable thickness of gravel mixed with irregular bands of fine sand and loam. The upper part is more uniformly of coarse gravel.

Near Keld there are several high terraces, possibly more than have been mapped. The various rocks near the river make features which are sometimes hard to distinguish from river-terraces, and the water may once have been over them, even if there is now little or no gravel left. The Swale here abounds in waterfalls and rapids, and we should in great part estimate the age of the terraces by the time taken to wear these rapids backwards.

J. R. D., C. T. C.

PEAT.

A large portion of the fell-tops and less steep valley-sides are covered with thick moss-peat. As one would expect, the growth is usually thickest and most constant where the drainage is least efficient; thus on Boulder Clay tracts it is very noticeable, but on limestones free of Drift it is rare. Its direct economical importance is not at present large, though in the remoter dales it is still cut for household-use, and in the lead-mining districts for the smelt-mills. In the mills it is mixed with a small portion of coke to help to keep the fire open.

Well-defined, basin-shaped peat-areas or bogs are rare. The Tom Hags, rather more than a quarter of a mile to the west-south-west of the hamlet of West Stonesdale, and the Stoóps Dub, three quarters of a mile east-north-east of Gunnerside, are both still partly tarns and partly bogs, but they are only small. A fine example of peat growing in a land-locked hollow occurs in Rushy Moor Bottom at the head of Mud Beck; a second somewhat similar mass lies a little further south.

Tree-stems are common in the peat at heights and situations where trees do not flourish now. Birch appears to be the commonest, but alder and oak are also not unfrequent. The oak is sometimes so sound that it can be used for ladders and other purposes. The following are some of the high localities where they have been observed, frequently near the bottom of the peat:—

In the sike a quarter of a mile south-east of the "t" of "Water Crag," over 2,050 feet. Near the bottom of the peat.

In the sike next west of the above, nearly 2,050 feet. Near the bottom of the peat.

On Muker Common a little south of the "r" of "Muker," over 2,000 feet.

South side of Wham Bottom (Gunnerside Beck), over 2,000 feet. Near the bottom of the peat.

South side of Great Punchard Head, between 1,900 and 2,000 feet. Near the bottom of the peat.

A little south-east of Satron High Walls, nearly 1,700 feet.

Near the head of Hard Level Gill, nearly 1,700 feet. Near the bottom of the peat.

Except where the bare rock comes to the surface or in the faces of the grit scarps, the whole of the Millstone Grit area may be said to be entirely peat-covered. For example, excepting the Water Crag Grit, nearly all but the escarpment between Punchard Head and Stonesdale is buried under peat ranging from 5 to 10 feet in thickness. About the head of William Gill the covering is particularly thick. It spreads over Ravenseat Moor in the same manner except that the grits form stronger features and are more often clear. In the intervening valley of West Stonesdale there is no peat, and partly in consequence of

this the valley is entirely grass-covered, as far up as its head at Tan Hill. We here enter a large peat area which stretches westward as far as Nine Standards and Coldbergh Edge, and thence southward to Birkdale Tarn.* The greater part of Birkdale Common west of the beck is covered with peat, as is also Angram Common and Abbotside. The peaty character of the ground is often indicated by the names, such as Tarn Moss, Lambs Moss, Short Moss Haggs, &c.

From Tan Hill northward to the edge of the map only the valleys are free of peat, Bowes Moor and Sleightholm Moor being entirely covered, except on Cocker Ridge. The great hollow north of Annaside Edge is partly overspread; the horizontal surface of the Ten-Fathom Grit is thickly covered, but the scarp-face is clear, and the same may be said of most of the beds as they crop out. East of a line drawn from the top of the Main Limestone at Ravens Park to the top of the same bed at Roe Beck, the valley on both sides is practically free of peat. Little patches do occur here and there but they are insignificant compared with the masses covering the rest of the ground.

C. T. C., G. B.

LANDSLIPS.

Many of the larger slips have evidently been helped by the dip of the beds being partly down hill; for example, the slips below Hooker Mill Scar, the north end of Kisdon Hill, Green Gill Bottom (Ivelet Beck), the north side of Thwaite Beck between Moor Close and Thwaite, Oxnop Beck, the south side of the east and west gill that comes into Gunnerside Beck from the west by the "G" of Gunnerside, part of the Winterings slip. But there are others, including those in the thick shales below the Millstone Grit on either side of West Stonesdale, and on the west side of East Stonesdale, and the very frequent sliding of banks of Boulder Clay, that cannot have been helped thus.

On the west side of Oxnop Beck the slipped ground in the Main and Underset Limestones presents a succession of scars each of which might at first be taken in turn to represent a natural feature formed by the base of the rock, were not other similar features visible. It is hard to say under how much of the slipped area there is limestone in place. The lowest limestone exposure is *in situ* as well as the highest, and as the dip of the beds is about equal to that of the slope from the top to the bottom of the area, the intervening space has probably itself also been once occupied by sound limestone, and many of the broken masses may be but little out of place.

C. T. C.

* It is worth mentioning that gulls breed on the shores of this tarn.

CAVES.

In Swinner Gill there is a cave called Swinnergill Kirk just under the waterfall over the chert on top of the Main Limestone, north of the North vein. The limestone dips steeply up stream, and the cave follows for a certain distance, so that all the water that comes down over the waterfall enters the cave and retraces its steps for this distance. It was once proposed to adopt the cave as a mine-level, and it was explored for about 140 yards. The water is said to come out to the surface again in the east bank of East Gill, as a strong spring in the Main Limestone.

The base of the Main Limestone contains a small cave in Aygill (Keld), and where it crosses Gunnerside Beck. In the last locality there are also various enlarged cave-like joints.

A cave of considerable extent was encountered many years ago in mining in the Main Limestone on the north side of Arkendale. In parts it was 30 feet high, with large stalactites hanging from the roof, some even reaching to the floor. It probably owed its origin to the underground stream which issues at Roughton Keld some distance above Dale Head Farm, and after a short course joins the main stream. The stalactites were broken up and many fragments carried away as garden-ornaments. The cave was afterwards filled up by the refuse from the lead-mine.

C. T. C., G. B.

CULTIVATION TERRACES.

There are prominent old cultivation-terraces, or "lazy beds," on the north side of the valley between Gunnerside and Ivelet. Such terraces are generally known in the North of England by the name of "Reins."

C. T. C.

NEOLITHIC FLINT-IMPLEMENTS.

Two flint-scrapers were discovered on the banks of the River Ure immediately below its source, and near the County Boundary. The flints were perhaps derived from the Yorkshire Chalk, none such occurring in the Glacial Drift of this district. The scrapers do not appear to have been much used. A somewhat doubtful flint-scraper was found by Mr. Powell of Towyn, near Abergele, at the Carbonate of Baryta Mine above Aysgarth. In character and colour it resembles those found at the source of the river.

C. E. R.

APPENDIX.

FOSSILS FROM THE CARBONIFEROUS LIMESTONE SERIES.

These fossils were collected several years ago by Prof. T. McK. Hughes, Mr. J. G. Goodchild, and R. Gibbs, late fossil-collector to the Geological Survey, and were identified by Mr. R. Etheridge, formerly Palæontologist to the Survey. They were obtained from numerous localities in the dales named below; the dales are indicated in the columns by letters as follows:—

E=Eden Valley.

S=Swaledale.

G=Garsdale.

W=Wensleydale.

R=Ravenstonedale.

	Great Scar Limestone.	Beds between Hardraw Scar Limestone.	Beds between Simonstone Limestone.	Beds between Middle Limestone.	Beds between Undersat Limestone.	Beds between Main Limestone.	Beds above.
PLANTS.							
<i>Calamites</i> - - -	..	..	..	..	W.	..	..
<i>Stigmaria ficoides, Brong.</i> -	..	..	W.	..	..	..	..
CORALS.							
<i>Alveolites septosa, Flem.</i> -	R.	..	..	..	..	G.	..
<i>Amplexus coralloidea, Sow.</i> -	E.	..	..	..	..	..	..
<i>Aulophyllum fungites, Flem.</i> -	..	..	..	..	..	G.	..
<i>Cladochonus</i> - - -	R.	..	..	..	..	..	..
<i>Cyathophyllum regium, Phil.</i> -	..	W.	..	..	..	..	..
" <i>sp.</i> -	R. W.	W.	..	W.	W.	..	..
<i>Lithostrotion junceum, Flem.</i> -	E.	..	..	..	W.	..	..
" <i>Martini, M. Edw.</i> -	R.	..	..	..	..	..	..
" <i>irregulare, Phil.</i> -	R.E.	W.	..	..	W.	..	..
<i>Syringopora ramulosa, Goldf.</i> -	..	W.	..	..	..	..	..
<i>Zaphrentis Phillipsi, M. Edw.</i> -	..	W.	..	W.	..	..	..
ECHINODERMATA.							
<i>Aotinoerinus</i> - - -	..	W.	..	..	..	..	..
<i>Archæopidaris</i> - - -	R.	..	..	..	..	..	..
<i>Potericrinus</i> - - -	..	W.	..	..	..	..	..
ANNELIDA.							
<i>Serpula parallela, M' Coy</i> -	..	..	..	..	..	..	W.
CRUSTACEA.							
<i>Griffithides globiceps, Portl.</i> -	..	..	..	W.	..	..	..
<i>Phillipsia</i> - - -	W.	..	..	..	..	..	..

	Great Scar Lime- stone.	Beds between. Hardraw Limestone.	Beds between. Simonside Lime- stone.	Beds between. Middle Limestone.	Beds between. Underset Lime- stone.	Beds between. Main Limestone.	Beds above.
POLYZOA.							
Ceripora - - -	..	W.	..	..	..	..	..
Encrinurus plebeius, <i>M'Coy</i> -	W.	W.	..	W.	W.	..	..
„ multiporata, <i>M'Coy</i> -	..	..	..	..	W.	..	..
„ sp. -	..	..	..	W.	..	..	W.
Polypora laxa, <i>Phil.</i> -	..	W.	..	..	..	..	..
Retepora -	..	..	..	W.	..	..	..
Rhombopora (<i>Vinoularia</i>) mul- tangularis, <i>Portl.</i> -	..	..	..	..	W.	..	..
BRACHIOPODA.							
Athyris ambiguus, <i>Sow.</i> -	R.	..	..	..	W.	..	..
„ expansa, <i>Phil.</i> -	..	..	..	W.	..	..	..
„ Roysii, <i>Leveillé</i> -	R.	W.	W.	W.	W.	..	..
„ sp. - - -	W.	..	..	W.	W.	G.	..
Camarophoria globulina, <i>Phil.</i> -	..	W.	..	..	..	..	..
Chonetes Buchiana, <i>De Kon.</i> -	..	..	..	W.	W.	..	..
„ laguessiana, <i>De Kon.</i> -	..	W.	W.	W.	..	..	..
„ papilionacea, <i>Phil.</i> -	..	W.	..	..	..	..	..
Cyrtina septosa, <i>Phil.</i> -	R.	..	..	..	..	..	..
Discina nitida, <i>Phil.</i> -	..	W.	..	..	..	..	S.
Lingula Credneri, <i>Gstnitz</i> -	..	..	..	..	W.	..	S.
„ mytiloides, <i>Sow.</i> -	..	..	..	W.	G.	..	..
„ squamiformis, <i>Phil.</i> -	..	..	..	..	G.	..	..
„ sp. -	..	W.	..	..	..	..	..
Orthis Michelini, <i>Leveillé</i> -	R.W.	W.	..	W.	W.	..	..
„ resupinata, <i>Mart.</i> -	..	W.	W.	..	W.	W.	..
Productus costatus, <i>Sow.</i> -	W.	W.	W.	W.	W.	..	..
„ fimbriatus, <i>Sow.</i> -	E.	..	..	W.	W.	..	..
„ giganteus, <i>Mart.</i> -	E.	..	W.	W.	W.	G.	..
„ llangollensis, <i>Dav.</i> -	W.	..	..	..	..	..	..
„ latissimus, <i>Sow.</i> -	..	..	W.	..	..	..	S.
„ longispinus, <i>Sow.</i> -	..	W.	..	W.	..	..	..
„ margaritaceus, <i>Phil.</i> -	W.	..	..	..	..	..	..
„ punctatus, <i>Mart.</i> -	R.	W.	W.	W.	W.	G.W.	..
„ pustulosus, <i>Phil.</i> -	W.	..	..	..	..	..	..
„ scabriculus, <i>Mart.</i> -	..	W.	W.	W.	W.	..	..

	Great Scar Lime- stone.	Beds between. Hardraw Scar Limestone.	Beds between. Simonskone Lime- stone.	Beds between. Middle Limestone.	Beds between. Underset Lime- stone.	Beds between. Main Limestone.	Beds above.
<i>Productus semireticulatus, Mart.</i>	R.W.	W.	W.	W.	W.	W.	W.
" <i>undiferus, De Kon.</i>	..	W.	..	..	..	..	..
" <i>youngiana, Dav.</i>	W.	..	..	..	..	..	..
" <i>sp.</i>	..	W.	..	..	..	W.	..
<i>Rhynchonella pleurodon, Phil.</i>	R.	W.	..	..	W.	W.	W.
" <i>sp.</i>	W.	W.	..	..	W.	..	..
<i>Spirifera convoluta, Phil.</i>	..	W.	..	..	..	..	..
" <i>duplicicosta, Phil.</i>	E.	..	..	..	..	..	..
" <i>glabra, Mart.</i>	..	W.	W.	..	W.?	W.	..
" <i>grandicostata, M'Coy</i>	..	..	..	W.	..	..	W.
" <i>lineata, Mart.</i>	..	W.	..	..	..	..	..
" <i>ovalls, Phil.</i>	..	..	..	..	W.	..	..
" <i>punguis, Sow.</i>	..	..	..	..	..	W.	..
" <i>striata, Mart.</i>	..	..	..	..	W.	..	W.
" <i>triangularis, Sow.</i>	..	W.	..	..	..	..	..
" <i>trigonalis, Mart.</i>	E.	W.	..	W.	..	W.	W.
" <i>sp.</i>	R.W.	W.	..	..	..	W.	..
<i>Spiriferina laminosa, M'Coy</i>	R.W.	W.	..	..	..	W.	..
<i>Streptorhynchus crenistria, Phil.</i>	R.W.	W.	W.	..	..	W.	W.
" <i>sp.</i>	..	..	..	..	..	W.	..
<i>Strophomena rhomboidalis, var. analogæ, Phil.</i>	W.	W.	..	..	W.	..	..
<i>Terebratula hastata, Sow.</i>	W.	..	..	..	..	..	..
" <i>sp.</i>	R.	..	..	..	..	..	..
LAMELLIBRANCHIATA.							
(Monomyaria.)							
<i>Aviculopecten arenosus, Phil.</i>	..	..	..	..	..	W.	..
" <i>asperulus, M'Coy</i>	..	W.	..	..	..	..	..
" <i>dissimilis, Phil.</i>	..	..	..	..	..	W.	G.
" <i>fimbriatus, Phil.</i>	..	..	..	..	..	W.	..
" <i>interstitialis, Phil.</i>	..	W.	..	..	..	W.	..
" <i>knockoniensis, M'Coy</i>	..	W.	..	..	..	W.	W.
" <i>micropterus, M'Coy</i>	..	W.	..	..	..	..	..
" <i>tessellatus, Phil.</i>	..	W.	..	..	..	..	..
" <i>sp.</i>	R.	..	..	..	W.	W.	..
<i>Pecten Sowerbyi, M'Coy</i>	..	W.	..	..	..	..	..
<i>Pinna flabelliformis, Mart.</i>	..	W.	..	..	..	W.	..
<i>Posidonomya vetusta, Sow.</i>	..	W.	..	..	..	..	..

	Great Scar Lime- stone.	Beds between. Hardraw Scar Limestone.	Beds between. Simonstone Lime- stone.	Beds between. Middle Limestone.	Beds between. Underset Lime- stone.	Beds between. Main Limestone.	Beds above.
<i>Pteronites persulcata</i> , <i>M' Coy</i>	..	W.	..	W.	..	..	..
„ <i>sp.</i>	..	..	W.	W.	..	..	..
(<i>Dimyaria</i> .)							
<i>Arca semicostata</i> , <i>M' Coy</i>	..	W.	..	..	..	..	..
<i>Cardiomorpha Egertoni</i> , <i>M' Coy</i>	..	..	..	W.	..	..	..
<i>Cypricardia modiolaris</i> , <i>M' Coy</i>	..	..	..	W.	..	..	..
<i>Dolabra equilateralis</i> , <i>M' Coy</i>	..	W.	..	..	..	..	..
<i>Leda attenuata</i> , <i>Flem.</i>	..	..	..	W.	..	..	..
„ <i>sp.</i>	..	W.	..	..	..	..	S.
<i>Lithodomus Jenkinsi</i> , <i>M' Coy</i>	..	..	..	W.	..	..	..
<i>Myalina</i> , <i>sp.</i>	..	..	..	..	W.	..	S.
<i>Nucula</i>	..	W.	..	..	..	W.	..
<i>Sanguinolites angustatus</i> , <i>Phil.</i>	..	..	..	W.	..	..	..
GASTEROPODA.							
<i>Acroculia</i> (<i>Capulus</i>)	R.	..	..	..	..	..	..
<i>Cylindritea carbonarius</i> , <i>De Kon.</i>	R.	..	..	..	..	..	..
<i>Eulima phillipsiana</i> , <i>De Kon.</i>	R.	..	..	..	..	..	..
<i>Euomphalus acutus</i> , <i>Sow.</i>	R.	..	..	..	..	..	..
„ <i>calyx</i> , <i>Phil.</i>	W.	..	..	..	..	..	..
„ <i>carbonarius</i> , <i>Sow.</i>	R.	W.	..	..	W.	..	S.
„ <i>Dionysii</i> , <i>Goldf.</i>	R.	..	..	..	..	..	..
„ <i>quadratus</i> , <i>M' Coy</i>	..	..	..	W.	..	..	..
„ <i>sp.</i>	..	W.	..	..	..	..	..
<i>Loxonema rugifera</i> , <i>Phil.</i>	R.	..	..	..	..	..	S.
„ <i>scalaroides</i> , <i>Phil.</i>	..	W.	..	..	..	..	..
„ <i>sulcatula</i> , <i>M' Coy</i>	..	..	..	W.	..	..	..
„ <i>ventricosa</i> , <i>De Kon.</i>	R.	..	..	..	..	..	..
<i>Natica</i>	R.	..	..	..	..	..	..
<i>Dentalium priscum</i> , <i>Goldf.</i>	..	W.	..	..	..	..	..
„ <i>sp.</i>	..	..	..	W.	..	..	..
HETEROPODA.							
<i>Bellerophon hialeus</i> , <i>Sow.</i>	E.	..	..	..	..	..	..
„ <i>sp.</i>	R.W.	W.	..	W.	..	G.	..
PTEROPODA.							
<i>Conularia quadrilobata</i> , <i>Sow.</i>	..	..	..	..	G.	..	..
„ <i>sp.</i>	..	..	..	..	W.	..	..

	Great Scar Lime- stone.	Beds between. Hardraw Scar Limestone.	Beds between. Simonstone Lime- stone.	Beds between. Middle Limestone.	Beds between. Underset Lime- stone.	Beds between. Main Limestone.	Beds above.
CERHALOPODA.							
<i>Discites subsulcatus, Phil.</i> - -	..	..	..	W.	..	..	..
" sp. - -	..	W.	..	..	..	..	..
<i>Goniatites bilinguis, Salt.</i> - -	..	..	..	..	W.	..	..
<i>Orthoceras</i> - -	W.	G.W.
PISCES.							
<i>Holoptychius</i> - -	W.	G.
<i>Petalodus</i> - -	R.
<i>Psammodus rugosus, Ag.</i> - -	R.
" sp. - -	W.

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